SMOKE HAZARD MANAGEMENT IN QUEENSLAND HOSPITALS – A CASE STUDY

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ABSTRACT

A fire in a large hospital can be not only mean a loss of infrastructure, but can be devastating in terms of the human loss, claiming the lives of many patients and staff. Smoke can be a major contributor to loss of life a building fire, and as such smoke control plays an important part in maintaining occupant safety in a fire. This is nowhere more important than in a hospital, where patients may be dependent upon staff to evacuate, or undergoing medical procedures that cannot be quickly terminated upon receipt of a fire alarm.

Smoke control in hospitals is vital to life safety during a fire event, and if not implemented correctly, or properly maintained, can have adverse consequences upon life safety. The refurbishment, expansion or upgrade of hospital buildings must take into account the existing smoke control methodology in the building. Through two Case Studies this report looks at how the continual refurbishment of a hospital can degrade the performance of a smoke control system installed in the building.

Modelling has been undertaken using BRANZFIRE to provide a comparison of the effectiveness of the smoke control measures between the smoke control measures as installed in Hospital A at construction and the smoke control measures as they currently exist in Hospital A.

An analysis of the existing smoke control in a large non-sprinklered hospital has been undertaken, based on site reviews and smoke control testing and reports undertaken by a fire engineering consultant. A brief review of the design process for a hospital smoke control system is undertaken on a sprinklered hospital currently under construction.

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GLOSSARY

The following definitions apply in this document. Definitions are based on the actual wording of the Building Code of Australia 2011 [1], and current Australian Standards.

Effective Height [1]

The height of the floor of the topmost storey (excluding the topmost storey if it contains only heating, ventilating, light or other equipment, water tanks or similar service units) from the floor of the lowest storey providing direct egress to a road or open space.

Fire Compartment [1]

A fire compartment means –

a) the total space of a building; or

b) when referred to in –

   i. the Objective, Functional Statement Or Performance Requirements – any part of a building separated from the remainder by barriers to fires such as walls and/or floors having an appropriate resistance to the spread of fire with any openings adequately protected: or

   ii. the Deemed to Satisfy Provisions – any part of a building separated from the remainder by walls and/or floors each having a fire resistance level not less than that required for a fire wall for that type of construction and where all openings in the separating construction are protected in accordance with the Deemed to Satisfy Provisions of the relevant Part.

Fire-affected Compartment [2]

A single area within a building required by building regulation for the control of fire or smoke, where a fire event has occurred. This area may be either a fire or smoke compartment.

Fire Resistance Level (FRL) [1]

The grading period, in minutes, determined in accordance with testing to AS 1530.4, or calculation based on a tested prototype, for the following criteria:

a) structural adequacy; and

b) integrity; and

c) insulation

and expressed in that order, e.g. 120/120/120.

Fire Source Feature [1]

A fire source feature means –

a) The far boundary of a road, river, lake or the like adjoining the allotment; or

b) A side or rear boundary of the allotment; or

c) An external wall of another building on the allotment which is not Class 10 building (i.e. not a non-habitable structure such as a carport, shed, or the like)

Fire Wall [1]

A wall with an appropriate resistance to the spread of fire that divides a storey or building into fire compartments.

Health Care Building [1]

A building whose occupants or patients undergoing medical treatment generally need physical assistance to evacuate the building during an emergency, and includes –

a) A public or private hospital; or

b) A nursing home or similar facility for sick or disabled persons needing full time care; or

c) A clinic, day surgery or procedure unit where the effects of the predominant treatment administered involve patients becoming non-ambulatory and requiring supervised medical care on the premises for some time after the treatment.

Horizontal Exit [1]

A required doorway between two parts of a building separated from each other by a fire wall.

Insulation [1]

In relation to an FRL, insulation is the ability to maintain a temperature on the surface not exposed to the furnace below the limits specified in AS 1530.4.

Integrity [1]

In relation to an FRL, integrity is the ability to resist the passage of flames and hot gases as specified in AS 1530.4.

Patient Care Area [1]

A part of a health-care building

Non-fire-affected Compartment [2]

Those areas within a building required by building regulation for the control of fire or smoke, where no fire (or smoke) has been detected, after the detection of fire (or smoke) in another compartment of the building.

Structural Adequacy [1]

In relation to an FRL, means the ability to maintain stability and adequate loadbearing capacity as determined by AS1530.4

Treatment Area [1]

An area within a patient care area, such as an operating theatre and rooms used for recovery, minor procedures, resuscitation, intensive care and coronary care from which a patient may not be readily moved.

Ward Area [1]

That part of a patient care area for resident patients and may contain areas for accommodation, sleeping, associated living and nursing facilities.

Zone Smoke Control Dampers [2]

All dampers, associated with a particular fire or smoke compartment or zone, which form part of a zone pressurisation smoke control system.

1. INTRODUCTION

1.1. GENERAL

Hospitals play a major, and very important, role in society. They provide emergency treatment, care and treatment for serious illness, and surgical capabilities, as well as acting as training centres for doctors and nurses. With the development of centralised health care facilities in large cities, the loss of a major hospital can have a serious negative impact upon the provision of health services for a large population. Similarly, the loss of a smaller hospital in remote areas can mean population centres are 400-500 km from the nearest hospital. Therefore, one would expect that the fire safety systems in hospitals, whether they are Deemed to Satisfy (DTS) with the Building Code of Australia (BCA) or are Alternative Building Solutions (ABS), would be fully documented, well maintained and regularly tested to ensure correct operation.

A fire in a large hospital can not only mean a loss of infrastructure, but can be devastating in terms of the human loss, claiming the lives of many patients and staff. Smoke can be a major contributor to loss of life a building fire, and as such smoke control plays an important part in maintaining occupant safety in a fire. This is nowhere more important than in a hospital, where patients may be dependent upon staff to evacuate, or undergoing medical procedures that cannot be quickly terminated upon receipt of a fire alarm.

1.2. AIMS AND OBJECTIVES

This project will investigate the implementation of smoke hazard management in hospitals in Queensland. In undertaking this project, the objectives to be reached are:

- Review the legislative requirements for smoke control in health care buildings.
- Highlight the difficulties associated with achieving functional and efficient smoke control measures in hospitals.
- Examine how smoke control strategy is changed by renovations to a hospital.
- Examine the design process for smoke control in a large hospital to determine the requirements driving the smoke control.
- Investigate the level of understanding of smoke hazard management requirements in hospitals.

This will be accomplished through case studies of two hospitals, one constructed circa 1980 and one currently under construction.

1.3. BACKGOUND

Over the last five years the author been involved in either fire systems auditing, fire systems design, or peer review of fire systems in several major hospitals in Queensland. These hospitals have been both public and private, and range from 30 year old hospitals, through to modern hospitals currently under construction. In carrying out this work, it has become apparent that hospital designers and fire safety consultants are often working at odds, and further, in some cases are not fully aware of the needs of the health provider and patient care services. This is specialised work on buildings with a high profile. It has also become evident that there are aspects where the ‘Deemed to Satisfy’ solution may be deficient.

Smoke hazard management is an area where the divergence between how an operational hospital would be best served by design and the direction that mechanical/fire safety engineers are pursuing in designing systems.

1.4. COMPLIANCE DOCUMENTS AND STANDARDS

In Queensland the primary reference for compliance is the National Construction Code Volume 1, Building Code of Australia Class 2 to Class 9 Buildings (BCA). The BCA contains Performance Requirements that must be met to ensure life safety and prevent fire spread. The Performance Requirements relating to smoke hazard management can be found in Appendix A. Compliance to these Performance Requirements can be demonstrated either by the use of the prescriptive solution (i.e. the Deemed to Satisfy solution) offered in the BCA, the use of alternative solutions developed by an appropriately qualified engineer, or a combination of both the preceding methods.

The BCA references Australian Standards to which design and installation of building elements and services must conform.

1.5. SMOKE CONTROL

AS/NZS 1668.1 [2] outlines three smoke control methods which may be utilised to achieve compliance with the standard, being system shutdown, air purge and zone pressurisation. Appendix B of the standard, which is informative only, recommends the use of System Shutdown or Zone Pressurisation only.

1.5.1. System Shutdown

System shutdown is a simple method of smoke control, whereby all air-handling plant is automatically stopped upon receipt of a fire signal. The objective of system shutdown is to restrict the spread of smoke from a fire affected compartment to a non-fire affected compartment via the air-handling system. [2] The main features of an AS/NZS 1668.1 system shutdown method of smoke control are:

1. Mechanical air-handling plant shall shut-down automatically upon receipt of a fire alarm.

2. Air-control dampers installed between all fire compartments served shall automatically close on receipt of a fire alarm.

3. Smoke dampers installed between all smoke compartments in health care buildings shall automatically close on receipt of a fire alarm.

1.5.2. Zone Pressurisation

Zone pressurisation is a method of smoke control whereby the fire affected compartment is exhausted and surrounding non-fire compartments are positively pressurised in relation to the fire affected compartment to prevent the spread of smoke from the fire affect compartment. The main features of an AS/NZS 1668.1 zone pressurisation system [2] are:

1. Smoke spill air from the fire affected compartment is discharged direct to atmosphere.

2. Return air/relief air from non-fire affected compartments is controlled.

3. Uncontaminated outside air is supplied or made up to all non-fire affected compartments.

4. Motorised dampers in mechanical ducting passing through fire walls bounding the fire affected compartment automatically close.

5. Fire doors in fire walls bounding the fire affected compartment automatically close.

6. Motorised dampers in smoke walls internal to the fire affected compartment automatically close.

7. Pressurisation of fire-isolated exits.

The primary effects of this arrangement are to restrict the spread of smoke to non-fire affected compartments, assist with the removal of smoke from the fire affected compartments, and restrict the spread of smoke into fire isolated exits and lift shafts. [2]

1.5.3. Sprinklers

It is generally agreed that sprinkler protection aids in smoke control in a fire event, and the BCA and AS/NZS 1668.1 recognise this by allowing the substitution of Zone Pressurisation with sprinkler protection to AS 2118.1 1999 [3] in health care buildings of more than two storeys but less than 25 m in effective height. Both sprinklers and zone pressurisation are required by the BCA for health care buildings over 25 m in effective height.

2. QUEENSLAND LEGISLATION REQUIREMENTS

2.1. INTRODUCTION

The legislative environment in Queensland that will be considered for this work includes the following:

- Building Act and Regulation
- Building Code of Australia Volume 1 2011
- AS/NZS 1668.1 1998
- AS 2118.1 1999

The Building Act and the Building Regulation 2006 are the primary legislation in force in Queensland at the time of writing.

The Queensland Building Act 1975 [4], hereafter called the Building Act, is the primary legislation for building work in Queensland. The Building Act [4] calls up the BCA [1] and the Queensland Development Code.

The Queensland Development Code consolidates Queensland specific building standards into a single document. The code covers Queensland matters outside the scope of, and in addition to, the Building Code of Australia, such as requirements for private health facilities.

The BCA is updated annually and adopted into Legislation by each Australian State and Territory to become the primary compliance document. The BCA calls up various Australian Standards for the testing, design and installation of building elements and building services.

The BCA provides a proscriptive method of achieving a ‘Deemed To Satisfy’ (DTS) fire strategy for a building, as well as outlining Performance Requirements that can be satisfied by a designer to achieve a performance based solution that offers, as a minimum, the same levels of safety as a DTS design.

BCA Clause A3.2 defines the classification of buildings in Australia. Under this clause a hospital is a Class 9a health care building. This classification includes those parts of the building set aside as a laboratory. The BCA goes on to lay out the DTS requirements for fire systems in all buildings in Australia and the Performance Requirements that a building is to meet, as well as the Performance Requirements required to be met by an Alternative Building Solution (ABS).

The following sections outline the BCA DTS requirements for Class 9a buildings. The Performance requirements relating to smoke hazard management can be found in Appendix A of this report.

2.2. TYPE OF CONSTRUCTION

The BCA defines three distinct types of construction, being Type A, Type B and Type C. Type A construction is the most fire resistant, with Type C being the least. Table 2.1 below summarises the Fire Resistance Level (FRL) requirements as laid out in Specification C1.1 of the BCA.

Table 2.1: FRL summary for types of construction defined in BCA

Building Element	FRL required to be achieved (minutes)		
	Type A Construction	Type B Construction	Type C Construction
External Wall (loadbearing)			
<1.5 m from a FSF[1]	120/120/120	120/120/120	90/90/90
<3 m from a FSF	120/90/90	120/90/96	60/60/60
>3 m from a FSF	120/60/30	120/30/30	-/-/-
>9 m from a FSF	120/60/30	120/30/-	-/-/-
>18 m from a FSF	120/60/30	-/-/-	-/-/-
External Wall (non-loadbearing)			
<1.5 m from a FSF	-/120/120	-/120/120	-/-/-
<3 m from a FSF	-/90/90	-/90/60	-/-/-
>3 m from a FSF	-/-/-	-/-/-	-/-/-
External Column			
<1.5 m from a FSF	120/-/-	120/-/-	90/-/-
<3 m from a FSF	120/-/-	-/-/-	60/-/-
>3 m from a FSF	120/-/-	-/-/-	-/-/-
Fire Walls	120/120/120	120/120/120	90/90/90
Internal Walls (loadbearing)	120/-/-	120/-/-	-/-/-
Fire Resisting Lift & Stair shafts	120/120/120	120/120/120	60/60/60
Other services shafts	120/90/90	Non-combustible construction	
Internal Columns	120/-/-	120/-/-	
Floors	120/120/120	30/30/30[2]	30/30/30[2]
Roofs	120/60/30	-/-/-	

Notes: 1. Fire Source Feature

2. For floors separating storeys or above a car park or storage area.

The type of construction required is determined from Clause C1.1 of the BCA, and is dependent upon the number of storeys, as summarised in Table 2.2 below.

Table 2.2: Type of construction required for Class 9a buildings

Number of Storeys	Type of Construction
1	C
2	B
3 or more	A

2.3. COMPARTMENTATION

Clause C2.2 of the BCA gives a maximum fire and smoke compartment size for each type of construction for a Class 9a building. This is further clarified in Clause C2.5 for patient care areas. Table 2.3 below provides a summary of the compartmentation requirements for class 9a buildings.

Table 2.3: Compartmentation requirements for Class 9a buildings

Type of Construction / Function of Area	Type of Compartmentation	Area Limitation (m^2)	Separating Wall FRL
Type A	Fire	5,000	120/120/120
Type B	Fire	3,500	120/120/120
Type C	Fire	2,000	
Patient Care Areas	Fire	2,000	120/120/120
Ward Areas	Fire	1,000	60/60/60
Ward Areas	Smoke	500	-/-/-
Ward Areas	Smoke	500	60/60/60[1]
Treatment Areas	Smoke	1000	-/-/-

Note: 1. This requirement is for Ward areas < $1000m^2$ in patient care areas < $2000m^2$

2.4. SMOKE HAZARD MANAGEMENT

Part E of the BCA deals with smoke hazard management requirements for all classes of buildings. The requirements for smoke hazard management differ depending upon the number of storeys contained or the effective height of the building.

The requirements include stair pressurisation, smoke alarm and detection and zone pressurisation. The requirements are summarised in Table 2.1, below.

Table 2.4: Smoke hazard management requirements for Class 9a buildings

Hospital Size	Smoke Hazard Management Requirements
Less than three (3) storeys	• An automatic smoke detection and alarm system complying with Specification E2.2a **AND** • Automatic shutdown of any air-handling system which does not form part of a zone smoke control system (other than individual room units with a capacity of not more than 1000 L/s, systems serving critical treatment areas and miscellaneous exhaust air systems installed in accordance with AS/NZS 1668.1) on the activation of a detection system.
Three storeys or more, but less than 25 m effective height	• An automatic air pressurisation system for fire-isolated exits in accordance with AS/NZS 1668.1 **AND** • Automatic shutdown of any air-handling system which does not form part of a zone smoke control system (other than individual room units with a capacity of not more than 1000 L/s, systems serving critical treatment areas and miscellaneous exhaust air systems installed in accordance with AS/NZS 1668.1) on the activation of a detection system. **AND** • Either: – A zone smoke control system in accordance with AS/NZS 1668.1 **OR** – An automatic fire sprinkler system complying with AS 2118.1[1]
Over 25 m effective height	• An automatic air pressurisation system for fire-isolated exits in accordance with AS/NZS 1668.1 **AND** • An automatic smoke detection and alarm system complying with Specification E2.2a **AND** • A zone smoke control system in accordance with AS/NZS 1668.1 **AND** • An automatic fire sprinkler system complying with AS 2118.1[1]

Note: 1. Requirement articulated in Part E1, Clause E1.5 of the BCA [1]

2.5. AS/NZS 1668.1 1998 SMOKE CONTROL REQUIREMENTS

AS/NZS 1668.1 provides solutions for smoke control in health care buildings in Appendix B of the standard. This Appendix is *Informative*, i.e. for information and guidance only. Table 2.5 details the smoke control requirement for the categories of health care building defined in AS/NZS 1668.1 Appendix B.

Table 2.5: AS/NZS 1668.1 smoke control requirements for Class 9a buildings

Health Care Building Category	Health Care Building Size	Smoke Control Requirements
Category 1	Less than three (3) storeys	• Automatic shutdown of any air-handling system (other than systems serving critical patient care areas) on the activation of smoke detectors and, where practicable, any other installed fire detection or alarm system. • Smoke dampers installed in fire or smoke barriers in patient care areas should be activated to close.
Category 2	Three storeys or more, but less than 25 m effective height, and sprinkler protected	• Automatic shutdown of any air-handling system (other than systems serving critical patient care areas) on the activation of smoke detectors and, where practicable, any other installed fire detection or alarm system. • Smoke dampers installed in fire or smoke barriers in patient care areas should be activated to close. • An automatic air pressurisation system for fire-isolated exits.

Health Care Building Category	Health Care Building Size	Smoke Control Requirements
Category 3	Over 25 m effective height, or Three storeys or more, but less than 25 m effective height, and not sprinkler protected	• Any air-conditioning or ventilation system (other than systems serving critical patient areas) shall be automatically controlled to operate as a zone pressurisation system on the activation of smoke detectors and, where practicable, any other installed fire detection or alarm system. • The smoke control system in patient care areas should be capable of achieving a positive pressure of not less than 20 Pa and not more than 100 Pa in all non-fire affected compartments, relative to the fire-affected (smoke) compartment. • Smoke spill from a fire-affected compartment in a patient care area should be achieved by mechanical means. • Where smoke spill air-inlets are located in corridors only, the smoke-spill fan should be controlled by the activation of corridor smoke detectors only.

3. HEALTH DEPARTMENT REQUIREMENTS

The author was unable to obtain any detailed Queensland Health fire safety policy. The author understands that there is no detailed Queensland Health policy on fire safety, but that a design brief is issued for each hospital construction or refurbishment project undertaken, which incorporates the fire safety outcomes to be achieved for that individual project.

The Queensland Health Implementation Standard for Fire Safety identifies the minimum requirements that evidence the implementation of the fire safety elements of the Occupational Health and Safety (OH&S) policy in relation to Fire Safety. The document informs and provides an understanding of Queensland Health's strategies to manage fire risks. [5] This document is high level, and indicates that new building works, refurbishment and alterations shall be commissioned by the Queensland Fire and Rescue Service (QFRS) and the Building Certifier to ensure fire safety and building legislative compliance.

The Building Certifier acts as the Authority Having Jurisdiction (AHJ) for the building during design and construction. The Building Certifier performs building compliance and enforcement roles by ensuring that the builder attains compliance with the standards and building approval. This is formalised by the issuance of a compliance certificate stating that the building work complies with the building assessment provisions. The compliance of fire safety systems to Australian Standards and the BCA DTS provisions or the requirements of the ABS detailed in the Fire Engineering Report (FER) is covered under this compliance certificate.

The Implementation Standard for Fire Safety also outlines requirements for maintenance of fire safety systems and evacuation routes and exit doors. Smoke control is not specifically mentioned in this document; it does, however, refer the reader to the Australasian Health Facility Guidelines [6].

The Australasian Health Facility Guidelines (AHFG) deal mainly with the facilities and services requirements to design and construct a hospital capable of delivering efficient and effective medical services, and the specifics of fire safety in the hospital. The AHFG states that the following fire services should be considered in the design brief [6]:

- Fire detection and suppression systems;
- Hydrants and hose reels;
- Portable extinguishers;
- Smoke control and air pressurisation;

- Signs and evacuation plans;
- Warnings and information systems;
- Water supply; and
- Water storage.

The AHFG offers some high level guidance on these systems, which can be distilled down to ensuring compliance with the legislative requirements, i.e. the BCA. It also refers the reader to New South Wales Health Engineering Services and Sustainable Development Guidelines Technical Series TS11 [7].

TS11, prepared for NSW Health Asset & Contract Services, is intended as a handbook to be used during the briefing and design process. TS11 objectives are [7]:

- To allow the flexibility to facilitate creative/lateral thinking and innovation rather than adopting a prescriptive approach to design.
- To continually achieve better ways of delivering engineering services and sustainable development taking advantage of advances in technology.
- To drive cost efficiency in the provision of engineering services to achieve better value for money.
- To allow for the use of alternative/innovative materials and forms of service provision or designs, rather than being driven by the use of a prescriptive methodology. This then allow designs to be tailored to a particular building.

In relation to fire services, including smoke control, the objective of TS11 is 'to present a common set of criteria for fire services in a format which is accessible both to designers and those who brief designers. In general specific planning procedures and known design criteria have not been addressed… The core objective is to provide fire detection and suppression systems that meet the requirements of all relevant codes and functionality using cost-effective solutions that achieve an optimal balance between capital, operating and maintenance costs over the life of the service.' [7]

The document goes on to list the Codes and Standards that Fire Services are to be designed to meet, and general statements regarding design for cost effectiveness. Of note, is a comment under cost effectiveness is the following statement:

Health buildings shall be planned to minimise or avoid the need for sprinkler systems.

This implies that for hospitals of three storeys or more, but under 25 m in effective height, i.e. Category 2 hospitals as defined in Table 2.5, that zone pressurisation is the preferred method of achieving fire safety objectives. This may have been the case in Queensland at the time of construction of Hospital A in Case Study 1 of this document, but recent hospital projects, including the new Sunshine Coast University Hospital, show that Queensland Health is now changing direction, in that its design brief for new Category 2 hospitals shows a preference for sprinklers in such buildings, as opposed to zone pressurisation.

4. CASE STUDY 1 – HOSPITAL A

4.1. INTRODUCTION

Hospital A is an older hospital in a metropolitan region, serving a large population base. This hospital is one of many serving the greater Brisbane area, and as with most hospitals in Queensland, serves a large and aging population. The hospital was originally constructed circa 1980, under the Building Act 1975 [4] as amended in 1978.

4.1.1. Building Description

The hospital is a seven storey building providing 24-hour emergency medicine, general medicine, surgical services, cardiology, geriatric and rehabilitation services (GARS), gynaecology, orthopaedics, intensive and coronary care, neurology, gastroenterology, urology and urodynamics, and respiratory medicine. [8] Additionally, the hospital provides the following services:

a) oral health,

b) homecare,

c) breast screening, and

d) community health information management.[8]

Level 1 (Ground Floor) of the hospital contains Out Patients and allied Health Care facilities, such as Physio. The hospital kitchen, as well as a cafeteria and coffee shop are also on Level 1. The remainder of Level 1 consists of the Breast Clinic, Private Practice Clinics, Medical Records and Security Office.

The Operating Theatres are contained on Level 2, along with Day Surgery, Recovery, Surgical Wards and the Emergency Department. The air-handling units for the Operating Theatres are located in the Level 3 Plant Room, occupying approximately 30% of the floor area of Level 3. In addition to the Plant Room, Level 3 contains Wards, as well as Common Rooms for doctors. Levels 4 and 5 consist mainly of Wards and Hospital Administrative offices, as well as some Allied Health facilities. The upper levels, i.e. Level 6 and Level 7, consist of plant only.

Floor layouts are shown in Appendix B.

Hospital A contains the following fire safety systems:

a) Fire hydrant system,

b) Fire hose reels,

c) Fire Detection and Alarms

d) Sound System and Intercom System for Emergency Purposes,

e) Exit signs and emergency lighting, and

f) Zone pressurisation.

Hospital A is a non-sprinklered building.

4.2. BUILDING ACT 1975 DEEMED TO SATISFY REQUIREMENTS

Under the Building Act, as in force as the compliance document at the time of construction, Hospital A was built as a Class 9a 'institutional building', i.e. a building 'designed, constructed or adapted as a clinic, convalescent home, hospital, infirmary…' [4] The hospital was required under the Building Act 1975 to be of Type 1 construction, i.e. the most fire resisting type of construction.

The following sections provide an overview of the fire safety requirements for the hospital under the Building Act 1975. The Building Act 1975 was a prescriptive document, with little recognition of performance based solutions. With this in mind, compliance with the requirements of the Building Act 1975 would be expected in the original construction. What is less certain is the impact of the various upgrades and extensions carried out on the smoke hazard managements systems. This will be further explored in Section 4.5.

4.2.1. Fire Resistance

As a five (5) storey Class 9a building, the hospital was required to be of Type 1 construction (note that under the Building Act 1975 as in force in 1982, construction was designated numerically, Type 1 being the most fire resistance through to Type 5 being the least fire resistant, as opposed to the current BCA, which defines Type A, Type B and Type C construction). Generally, the building was required to be constructed to achieve a 120 minute fire resistance, as shown in Table 4.1.

Table 4.1: FRL summary for Type 1 construction as defined in the Building Act 1975

Building Element	FRL required to be achieved (hours)
	Type 1 Construction
External Wall (loadbearing)	
<4.5 m from a FSF[1]	3
<6 m from a FSF	2
>6 m from a FSF	2
External Wall (non-loadbearing)	
<4.5 m from a FSF	3
<6 m from a FSF	2
<7.5 m from a FSF	1.5
<9 m from a FSF	1
External Column	
<4.5 m from a FSF[1]	3
<6 m from a FSF	2
>6 m from a FSF	2
Fire Walls	4
Internal Walls (loadbearing)	2
Fire Resisting Lift & Stair shafts	2
Other services shafts	1.5
Internal Columns	2
Floors	2
Roofs	2

Notes: 1. Fire Source Feature

There are no limits to the size of compartments in a building of Type 1 construction listed in the Building Act 1975.

4.2.2. Fire Fighting Equipment

The following fire fighting equipment is required by the Building Act to be installed in the hospital:

1. Internal fire hydrant system located in fire isolated stairs.

2. Fire hose reel system to AS1221 [9] throughout the building.

3. Portable fire extinguishers to AS CA18 [10] throughout the building.

4. Fire Brigade hydrant boosters are to be provided at street level to assist attending Fire Brigade.

These fire safety systems as installed are compliant with Deemed to Satisfy requirements of the Building Act 1975.

4.2.3. Exit Lighting, Exit Signs and Warning Systems

Emergency lighting and exit signage is required throughout the building. Such systems are expected to identify the location of available required exits and the path of travel to those exits, allowing occupants to exit the building in an emergency.

Additionally, a Sound System and Intercom System for Emergency Purposes (SSEP) to AS1670.4 is required throughout the building.

These fire safety systems as installed are compliant with Deemed to Satisfy requirements of the Building Act 1975, and meet the intent of TS11 [7].

4.2.4. Smoke Hazard Management

As a Class 9a building with more than three storeys, but an effective height of less than 25m, the BCA (i.e. the BCA 2011) Table E2.2 requires the following smoke hazard management measures to be provided throughout Hospital A:

a) An automatic smoke detection and alarm system, and

b) Any ducted air-handling system which is designed to recirculate air in the building shall be so installed that–

    i. in the event of a fire the system shall operate automatically so that there shall be no re-circulation of air and all air shall be exhausted outside the building in a position approved by the Local Authority; and

    ii. the action referred to paragraph i. shall be arranged to take place by the actuation of a smoke detector at the end of the return air shaft, such detector being or a type suitable for monitoring the presence of smoke in air streams.

4.3. BCA 2011 DEEMED TO SATISFY REQUIREMENTS

Although this building was built some thirty years ago it will be assessed against the DTS requirements of the BCA 2011 to show how the fire safety system requirements have changed in Queensland over the last 30 years. It should be noted that no records can be found of Fire Engineered solutions in this building prior to 2008, so it can be assumed that the building was built to the standards of the day, including the installation of compliant smoke hazard management systems.

4.3.1. Fire Resistance

As a seven storey Class 9a building, the hospital is required to be of Type A construction. Generally, the building is required to be constructed to achieve a 120 minute fire resistance, as shown in Table 2.1.

The compartmentation requirements for Hospital A are shown in Table 2.3.

4.3.2. Fire Fighting Equipment

The following fire fighting equipment is required by the BCA to be installed in the hospital:

1. Internal fire hydrant system to AS2419.1 shall be installed throughout the building, located in fire isolated stairs.

2. Fire hose reel system to AS2441 shall be installed throughout the building.

3. Portable fire extinguishers to AS2444 shall be installed throughout the building.

4. A fire control centre shall be provided at Ground Level, to assist attending Fire Brigade personnel.

5. Fire Brigade hydrant boosters to AS 2419.1 shall be provided at street level to assist attending Fire Brigade.

These fire safety systems as installed are compliant with Deemed to Satisfy requirements of the BCA and the relevant standards.

4.3.3. Exit Lighting, Exit Signs and Warning Systems

Emergency lighting and exit signage to AS2293.1 shall be installed throughout the building. Such systems are expected to identify the location of available required exits and the path of travel to those exits, allowing occupants to exit the building in an emergency. Additionally, a Sound System and Intercom System for Emergency Purposes (SSEP) to AS1670.4 is required throughout the building.

New South Wales Health Engineering Services and Sustainable Development Guidelines TS11 [7] states that ‘a fire alarm sounding within the building may cause extreme anxiety in some patients leading to an elevated health risk, especially for bed bound patients.' TS11 [7] goes on to list the following measures that should be considered as part of the SSEP:

a) Nurse call system transmitted fire alarm messages,

b) PA Coded announcement for hospital staff,

c) Flashing strobe lights which would activate on a General Fire Alarm (GFA) rather than an audible alarm

d) PA announcements to general public in conjunction with alarm tone announcement, and

e) PA systems must have an emergency channel.

These fire safety systems as installed meet and exceed the requirements of the building Act 1975, and are compliant with Deemed to Satisfy requirements of the BCA and the relevant standards; additionally, the implementation of these systems meets the intent of the TS11 [7] considerations.

4.3.4. Smoke Hazard Management

As a Class 9a building with more than three (3) storeys, but an effective height of less than 25 m, the BCA Table E2.2 requires the following smoke hazard management measures to be provided throughout Hospital A:

a) An automatic smoke detection and alarm system complying with BCA Specification E2.2a, AND

b) An automatic air pressurisation system for fire-isolated exits in accordance with AS/NZS 1668.1 AND

c) Automatic shutdown of any air-handling system which does not form part of a zone smoke control system (other than individual room units with a capacity of not more than 1000 L/s, systems serving critical treatment areas and miscellaneous exhaust air systems installed in accordance with Section 5 and Section 11 of AS/NZS 1668.1) on the activation of:

   i. Smoke detectors installed in accordance with (a): **AND**

   ii. Any other installed fire detection and alarm system including a sprinkler system complying with Specification E1.5; **AND**

d) Either:

i. A zone smoke control system in accordance with AS/NZS 1668.1 [2] **OR**

ii. An automatic fire sprinkler system complying with Specification E1.5 throughout with residential sprinkler heads in patient care areas. **AND**

e) Sound System and Intercom System for Emergency Purposes (SSEP) to AS 1670.4 throughout the building.

BCA Specification E2.2a adds the following requirements to the above:

a) The smoke detection system is to comply with AS 1670.1, except for the provisions of Clause 3.26(f).

b) The smoke detection system is to activate a building occupant warning system.

c) Photoelectric type smoke detectors must be installed in patient care areas and in paths of travel to exits from patient care areas.

d) Manual Call Points (MCP) must be installed in evacuation routes so that no point on a floor is more than 30 m from an MCP.

4.4. SMOKE HAZARD MANAGEMENT SYSTEM

The smoke hazard management system in Hospital A is based on the following:

1. Shutdown of air-handling units serving the fire affected compartment,

2. Smoke exhaust utilising air-handling unit return air and dedicated smoke spill fans, and

3. Operation of air-handling units in full outside air mode, with no return air, in all other fire compartments to create a pressure differential with the fire affected compartment.

The above outline of the smoke hazard management system is as per the latest mechanical drawings and Fire Engineering Report, dated October 2009 [11], that the author has access to, as well as testing of the system undertaken by a fire engineering consultant in 2011.

4.4.1. Smoke Hazard Management

According a consultant's report into the Smoke Control Systems in Hospital A [12] produced in 2011 the original smoke control system installed in the building worked on vertical compartmentation, and would have been commissioned to the approvals of the day, i.e. circa 1982. The consultant's report states 'the arrangement of the original detection system was fire zones vertically which aligned closely to the air-handling groups in the risers. This means the building had an up-down smoke control method to contain smoke in one vertical compartment, which has not been maintained with the upgrades to the building.'

The original building was designed with two main plant-rooms, on Level 3 and Level 6. The Level 3 plant-room services the operating theatres on Level 2, and the Level 6 plant-room services individual floors, via central air-handling units. The central air-handling units in the Level 6 plant room feed into two main vertical risers supplying various zones on every floor in the building. Additional air handlers on Level 3 feed out across to individual perimeter zones and individual operating theatres with dedicated exhaust and pressure controls. A schematic representation of the air-conditioning zones on Level 2 is shown in Figure 4.1, below. Note that coverage areas are approximate, based on information contained in the fire matrix produced in 2012 [13].

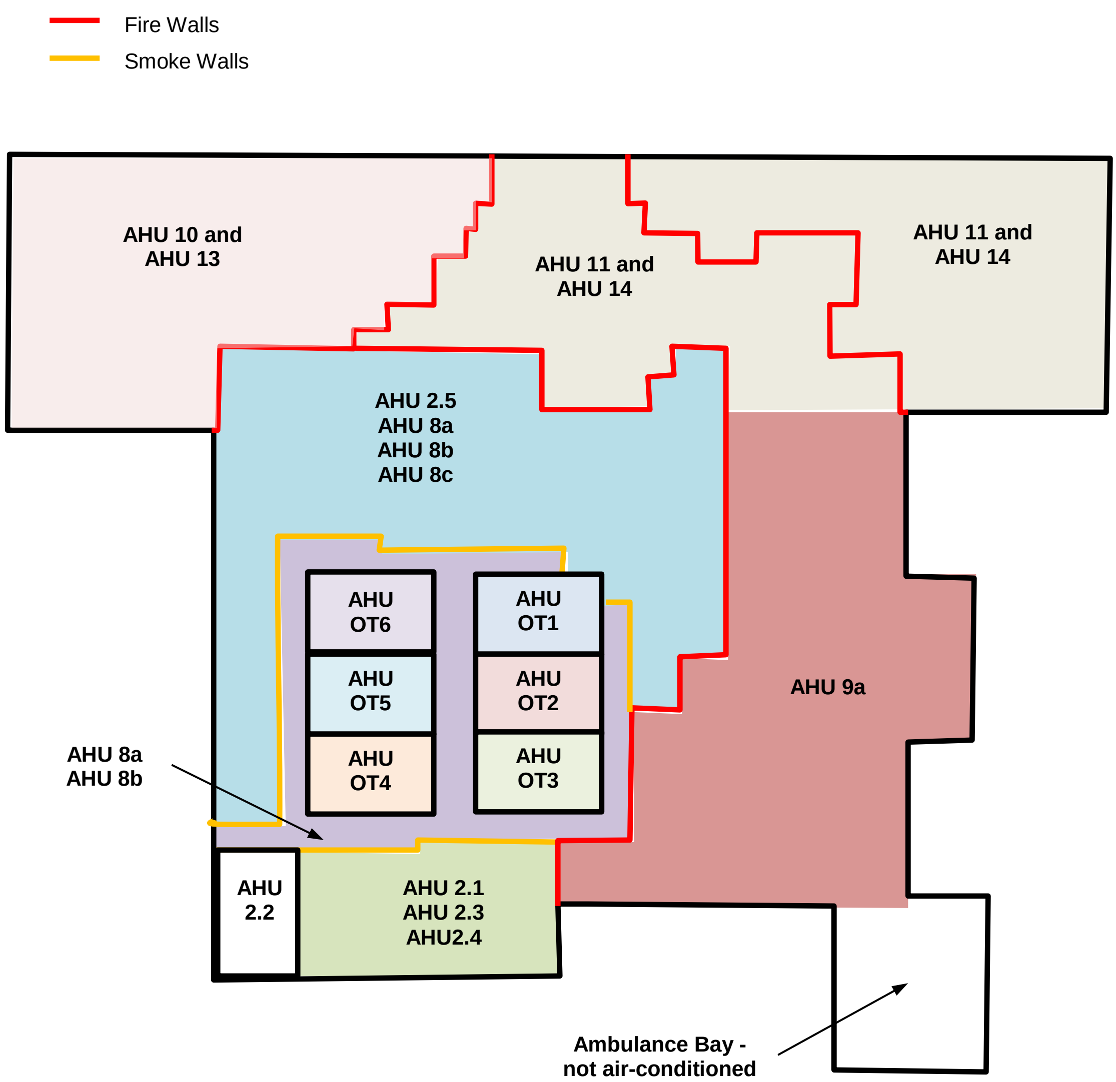

Figure 4.1: Level 2 Air-Conditioning Zones

Some of these systems have dedicated fire mode operations either with supply air or dedicated return air that is used to spill combustion products out of the building via the general and toilet exhausts. The arrangement of the original detection system was fire zones vertically which aligned closely to the air-handling groups in the risers. This means the building had an up-down smoke control method to contain smoke in one vertical compartment, which has not been maintained with the upgrades to the building.

New code requirements since 1993 and AS/NZS 1668.1 alter the smoke control systems to floor-by-floor pressurisation and stairwell pressurisation, which has not been implemented in this building. Some parts show the introduction of smoke and firewalls with smoke dampers motorised to contain the smoke to one of the ends. Unfortunately, many of these walls have been breached with penetrations, poor fitting duct work with no sealing of smoke and no smoke dampers fitted.

Since the initial construction of the building there have been a series of refurbishments and extensions undertaken throughout the hospital. Each of these has involved, to a greater or lesser extent, work on the smoke control system. The author been unable to find any evidence that suggests changes to the smoke control system have been carried out with a systematic and integrated approach designed to maintain the integrity of the system in place.

The exception to this is the 1996 refurbishments, which appear to have involved documenting the existing smoke control system, with the aim of moving to a horizontal or floor-by-floor zone pressurisation smoke control methodology. However, even this approach has failed to account for the changed fire and smoke compartmentation on each level of the building.

4.4.2. Compartmentation

It is assumed, given the absence of any evidence to the contrary, that the building was initially built with fire and smoke compartmentation as required by the extant regulations of the day. Throughout the life of the hospital, with the various refurbishments and extensions that have been undertaken, the compartmentation has been changed and does not comply with current legislation. Fire and smoke compartmentation within the hospital as it currently stands is shown in Figures 4.1 – 4.5 below. Note that these figures do not show the new emergency department on Level 2 and extended compartments on Level 1, which are under construction at the time of writing.

Level 1 is divided into three fire compartments, with Out Patients Department (OPD) forming one fire compartment, Medical Records a second fire compartment, and the remainder of floor being the third fire compartment. OPD is further divided into two smoke compartments. Compartmentation is shown below in Figure 4.2.

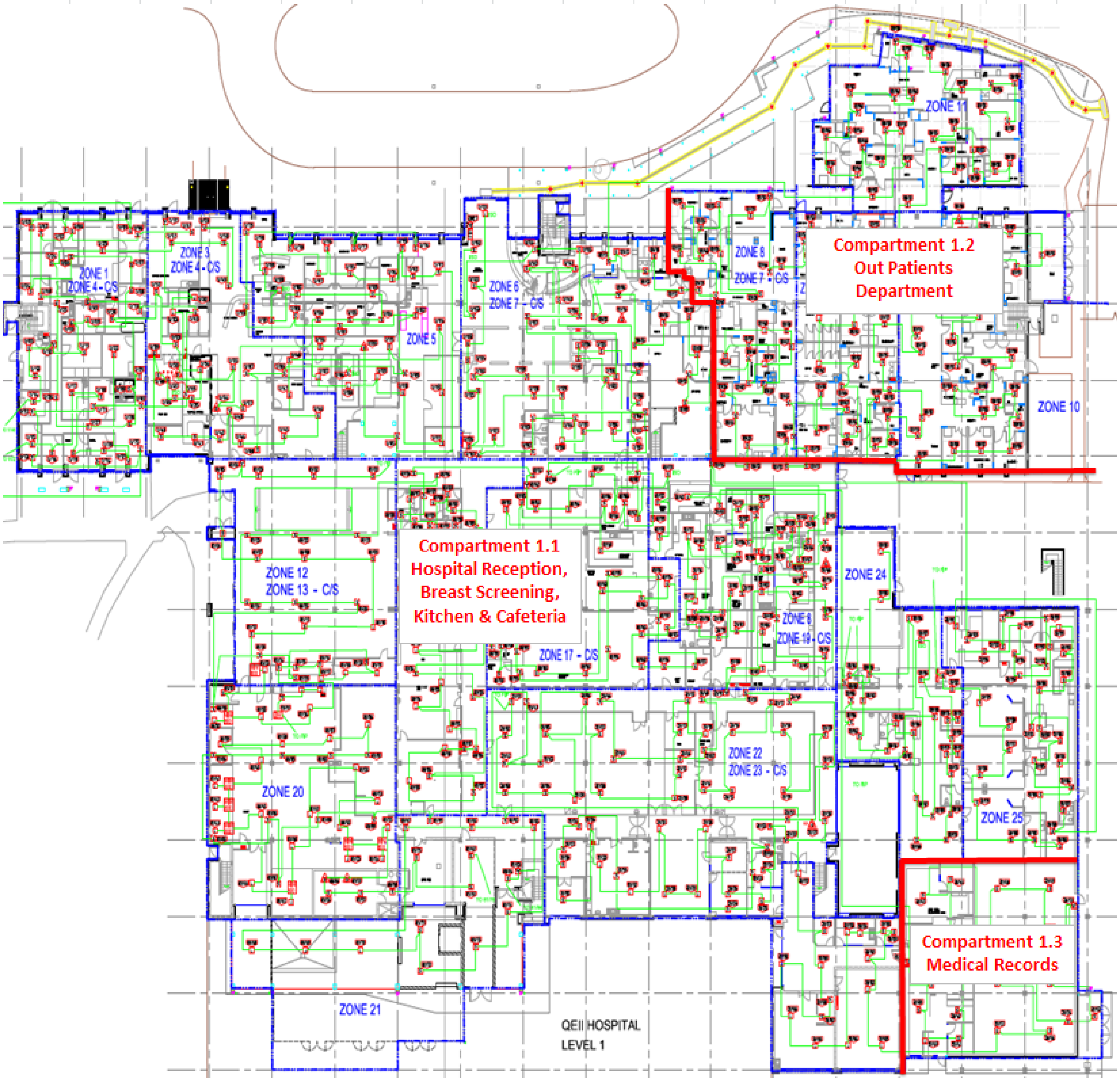

Figure 4.2: Level 1 Compartmentation

Level 2, containing the operating theatres, is divided into four fire compartments. Ward areas to the east and west of the building are separate fire compartments, each containing two smoke compartments. The Operating Theatres are a single fire compartment, with three smoke compartments contained therein. The remainder of Level 2, including the lift core, doctor's suites and the Emergency Department, makes up the fourth fire compartment. Compartmentation is shown below in Figure 4.3.

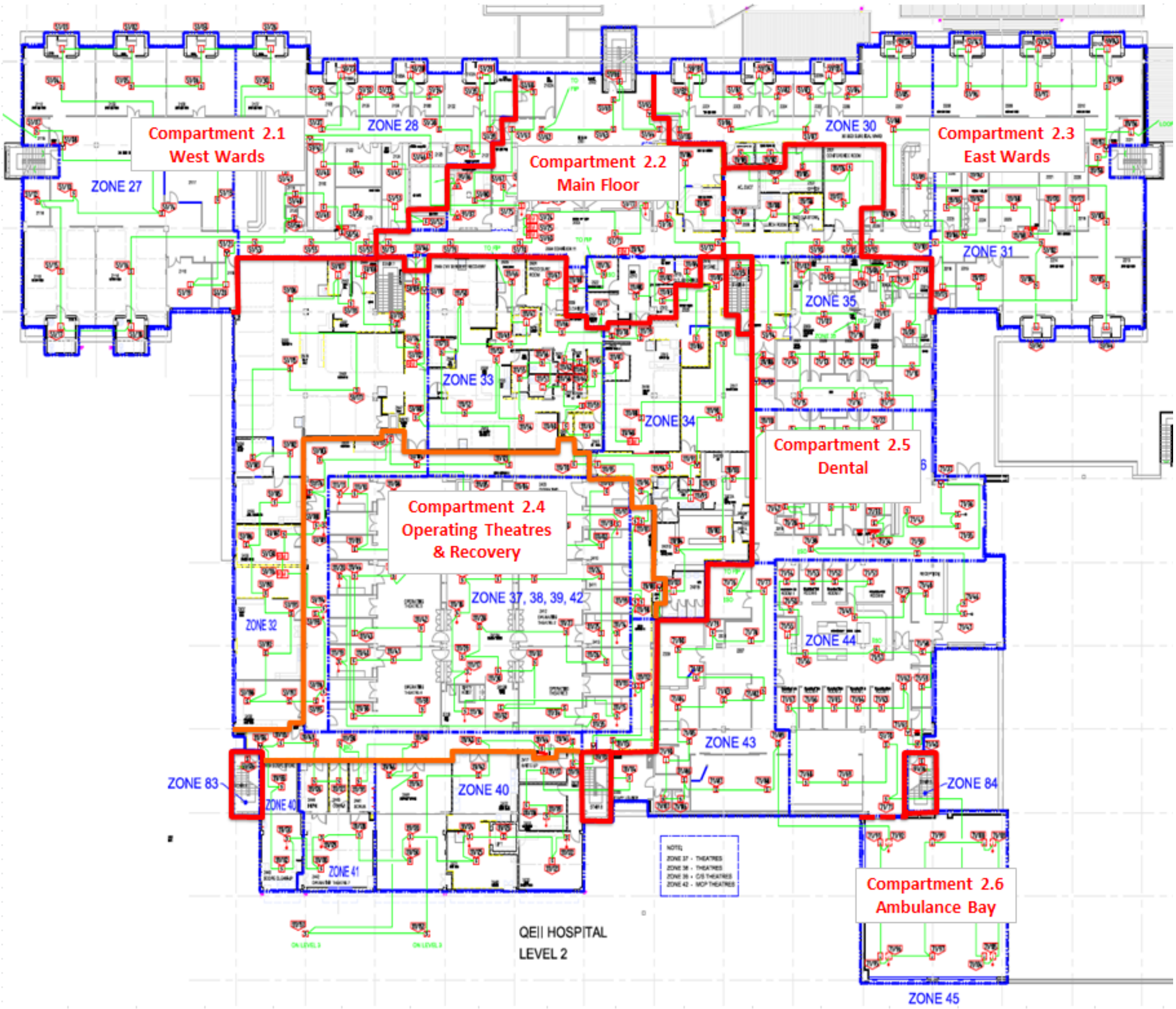

Figure 4.3: Level 2 Compartmentation

Level 3 contains seven separate fire compartments. The plant rooms to the southwest make up two fire compartments. The wards to the east and west of this level are fire separated, with each of these fire compartments containing two smoke compartments. The remainder of Level 3, including Dental and administrative areas, is the largest fire compartment on this level. Two small (<100m^2) areas containing Information Technology and communications hubs for the hospital are also fire separated. Compartmentation is shown below in Figure 4.4.

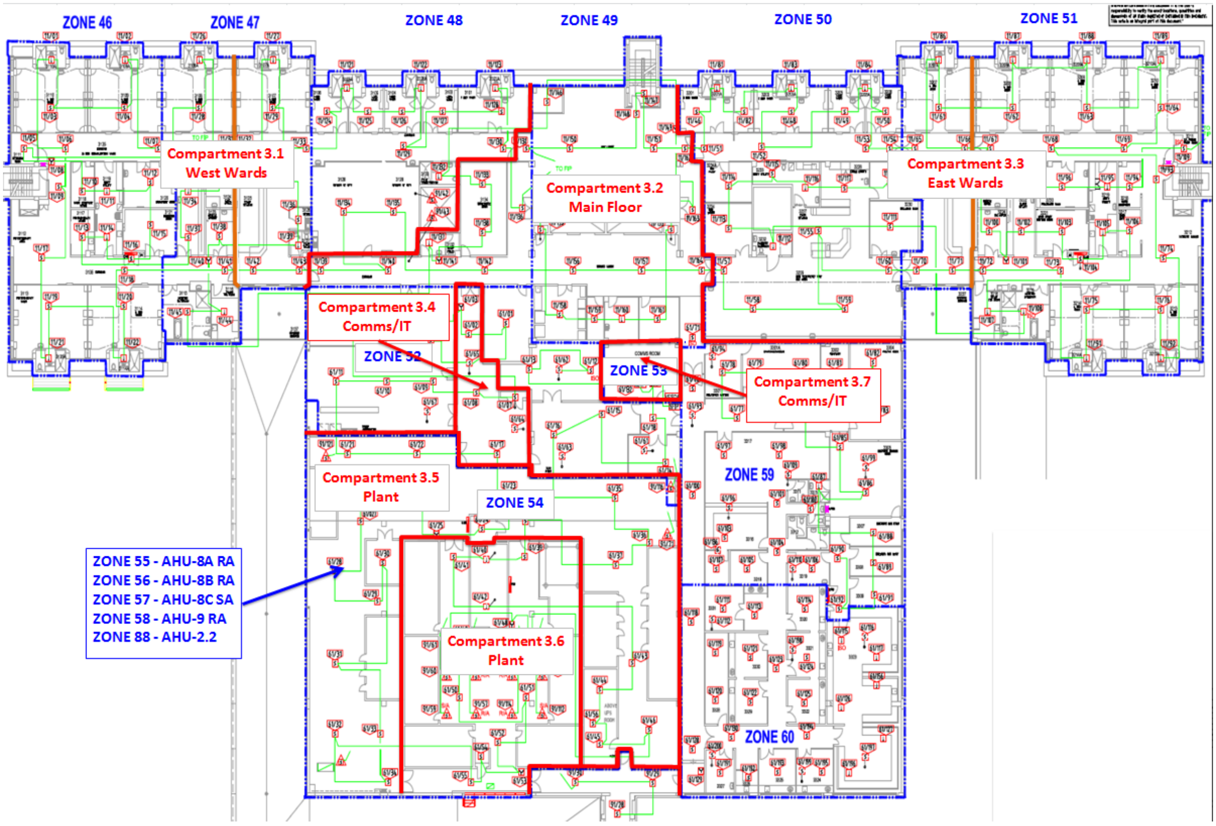

Figure 4.4: Level 3 Compartmentation

Levels 4 and 5, containing wards and administrative areas, are divided into two fire compartments each; with each fire compartment containing two smoke compartments. Compartmentation for Level 4 and level 5 is shown below in Figure 4.5 and Figure 4.6 respectively.

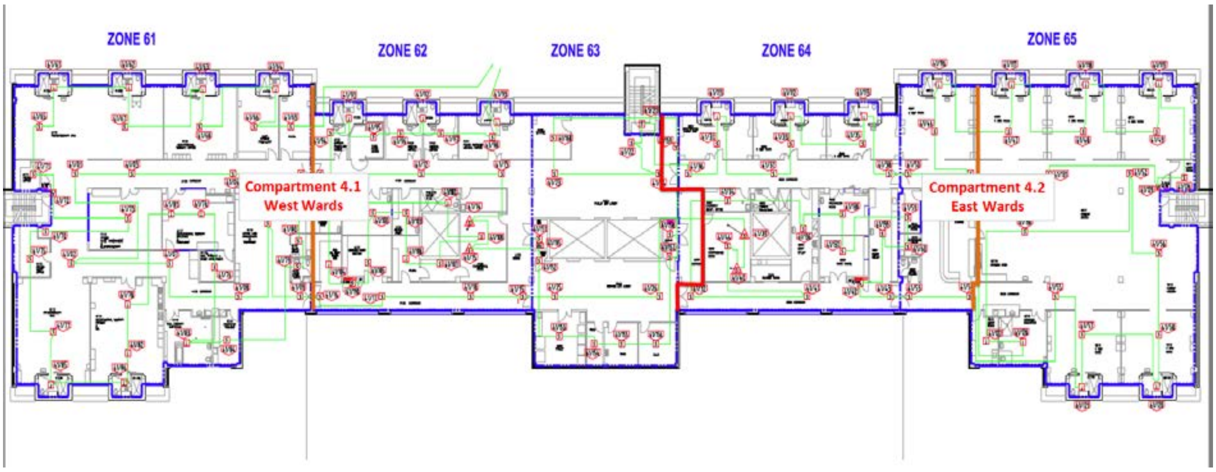

Figure 4.5: Level 4 Compartmentation

Figure 4.6: Level 5 Compartmentation

4.4.3. Smoke Exhaust

Smoke exhaust is provided to most fire compartments throughout the hospital. , below, summarises the smoke exhaust provided throughout he hospital.

Table 4.2: Smoke Exhaust Installed

Level	Compartment	Smoke Exhaust Quantity (m^3/s)	Comments
1	Main Floor	Nil-	
	Out Patients	6	A single smoke spill fan serves both smoke compartments, with a motorised damper directing exhaust form the fire affected compartment
	Medical Records	Unknown	Believed to be 6-9 m^3/s, but not able to be confirmed by author
2	Main Floor	Unknown	Unable to determine from information available. Potentially approximately $10m^3/s$ based on use of AHU return air as exhaust.
	East Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls.
	West Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls
	Operating Theatres	6	Fans located on Level 3

Level	Compartment	Smoke Exhaust Quantity (m^3/s)	Comments
3	Plantroom 1 and 2	Nil	General exhaust fans only providing smoke spill
	Main Floor	Unknown	Unable to determine from information available. Potentially approximately $10m^3/s$ based on use of AHU return air as exhaust.
	East Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls
	West Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls
	Communications and IT	Nil	Suppression system installed to this area
4	East Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls
	West Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls
5	East Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls
	West Wards	12	$6m^3/s$ from smoke spill fan serving one smoke compartment and $6m^3/s$ from AHU return air serving the other . Exhausts entire smoke compartment via vents in the ceiling plenum of the smoke walls

A cause and effect matrix for the hospital smoke exhaust was produced in 2007 [14] but appears to contradict the mechanical drawings available to the author, and does not match the actual results from fire alarm testing conducted in 2011 [15], which are discussed in Section 4.8.

There are no stair pressurisation systems installed within the building.

4.5. BUILDING WORKS

Initially built in the 1980's, Hospital A has undergone many renovations and expansions in its history. These range from ward fit-outs through to theatre expansions, and the addition of a new Emergency Department. As far as the author has been able to determine, the following list of works have been conducted:

1. Circa 1996 the smoke control system to Levels 2 – 5 was upgraded with two smoke exhaust fans servings Level 2 through Level 5 installed, and Level 1 was refurbished, with extensions to the southern end of the building. During these works the smoke exhaust in the Medical Records room was upgraded, with a new smoke exhaust fan being installed in a dedicated plant room, and ducting serving the air-conditioning system being rerouted.

2. Circa 2001 Level 5 was refurbished, with fire and smoke walls being relocated in parts.

3. In 2008 the Ground Floor Out Patients area was extended and renovated, as was the Theatre Area on Level 2, Plant Rooms on Level 3, and the Ward Area on Level 5. A Fire Engineering Report (FER) was produced for these extensions and refurbishments, the only FER for this building the author has been able to locate. Alternate Solutions for extended distance between alternate exits, oversized smoke and fire compartments and limited fire hose reel coverage on Level 2 were approved via this FER.

4. In 2011 the western wing of Level 4 was refurbished. These works did not involve an Alternative Solution.

5. Currently an extension to Level 1 containing a new Endoscopy unit is being constructed, and the Level 2 Emergency Room is being extended. These works do not involve an Alternative Solution for smoke control, and Queensland Health policy is to avoid Alternative Solutions where possible.

In between these refurbishments and extensions minor works have been carried out on all levels of the hospital, but the author has been unable to obtain details of these works. The following sections provide detail on the original construction, the 1996 and 2008 refurbishments, and the associated effects on smoke control.

4.5.1. Original Construction

As stated in the conclusions of the consultant's report, Smoke Control Systems in Hospital A [12], the original smoke control system fitted to the building provided a sandwich zone pressurisation system, with the fire affected floor being exhausted, and all other levels being pressurised by the air-conditioning system in full outside air mode. Central air-conditioning plant on Levels 6 and 7 serves Levels 4 and 5, and part of Levels 1, 2 and 3. Two mechanical risers support this arrangement.

The Level 3 plant room contains the AHUs for the Operating Theatres on Level 2, as well as AHUs serving the remainder of Level 3. Medical Records and OPD on Level 1 were served by plant located on Level 1.

As stated above, the smoke control strategy adopted by the original construction is one of zone pressurisation based on Levels. This is enabled by the two mechanical risers serving all levels of the hospital. To suit this approach to smoke control the compartmentation provided in the original build was generally floor by floor, with the exception of the Operating Theatres on Level 2 and the Plant areas on Level 3. Therefore, Level 5 would have been a single fire compartment, as would Level 4. Level 3 would have been two fire compartments, with the Plant Room being fire separated from the Health Care areas, but it is unknown whether the Communications/IT areas currently fire separated on Level 3 existed in the original building. The Operating Theatres on Level 2 would have been fire separated from the remainder of the floor, creating two fire compartments on this Level. The Out Patients Department and Medical Records area on Level 1 would both have been fire separated from the remainder of the floor in the original construction, although the original Out Patients Department was smaller than now.

Figure 4.7 and Figure 4.8 show a schematic of the smoke control arrangements for a fire event on a typical level. The schematic shows the fire level as being Level 4, with Levels 3 and 5 being shown. For clarity, only the exhaust air path and associated motorised dampers are shown in the schematic.

The smoke control philosophy is summarised as follows:

- Smoke detection activates on fire affected level.
- Supply air dampers to the fire affected floor close.
- Supply air dampers to non-fire affected floors remain fully open.
- Outside air dampers on AHUs moves to fully open, supplying 100% outside air to non-fire affected floors.
- Return air dampers on fire affected floor remain open, providing a smoke spill path through the ceiling plenum to atmosphere above the roof, via the mechanical riser.

– Return air dampers on non-fire affected floor close, pressurising these levels.

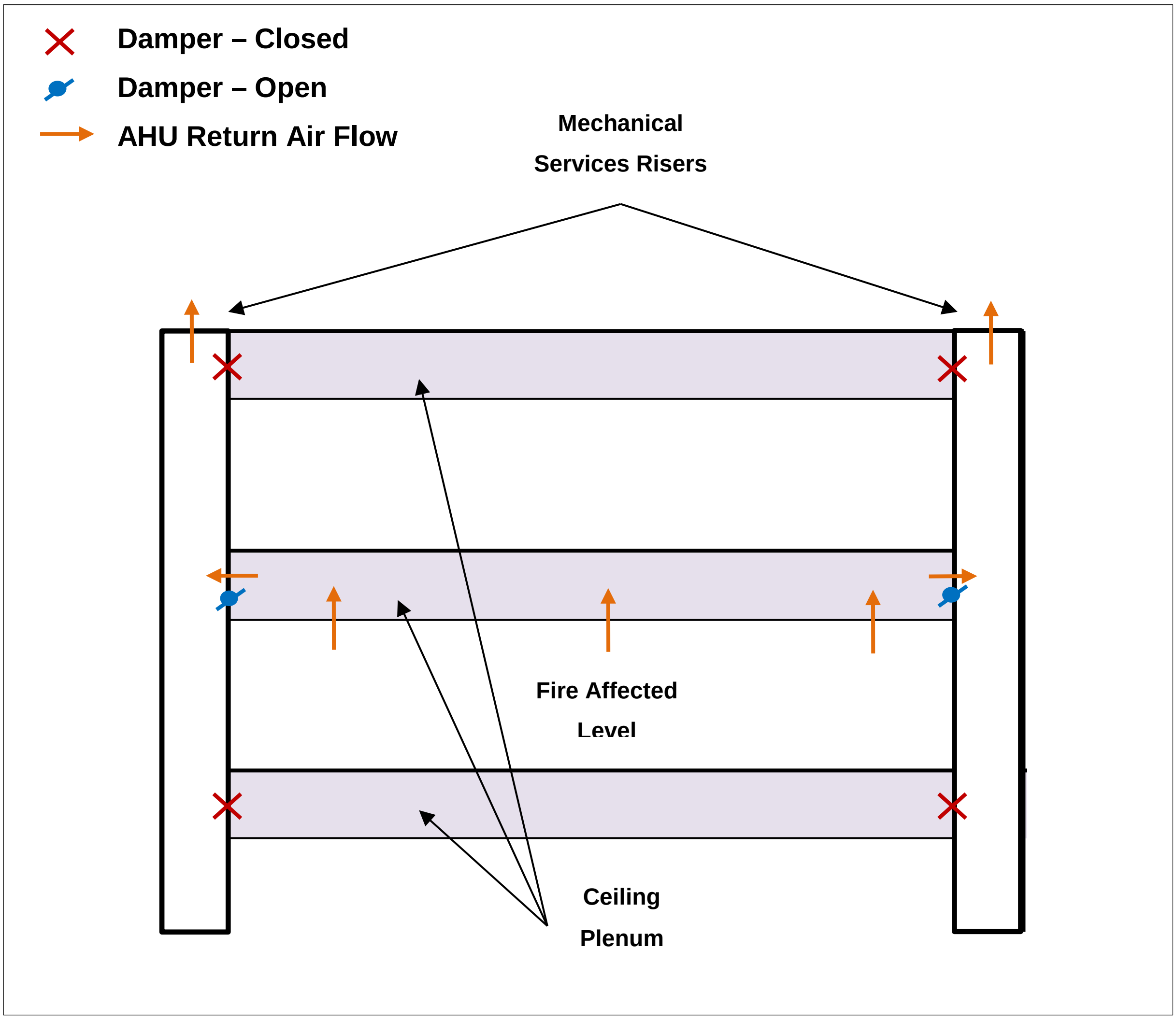

Figure 4.7: Smoke Exhaust Schematic – Original Construction (elevation)

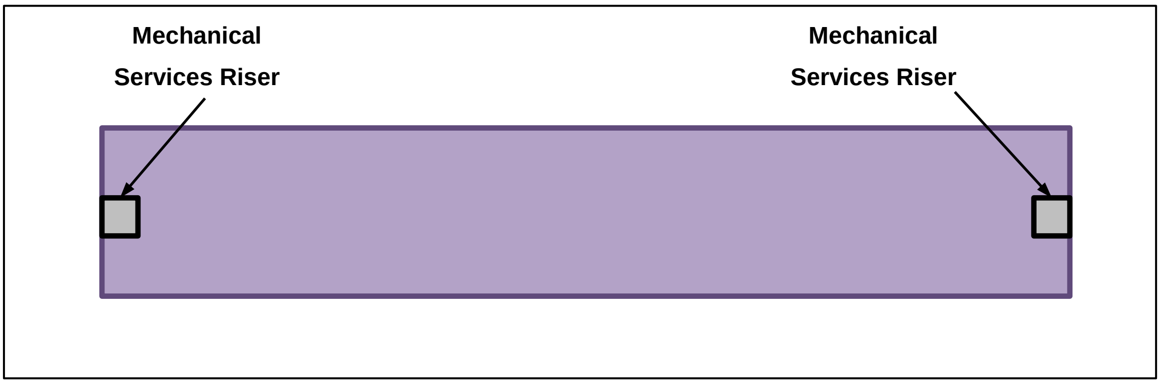

Figure 4.8: Smoke Exhaust Schematic – Original construction (plan)

4.5.2. 1996 Refurbishment and Upgrade of Smoke Hazard Management System

In 1996 a major refurbishment of the hospital was undertaken. As part of these works the smoke hazard management system was upgraded in key areas. From mechanical drawings that have been made available the upgrade undertaken involved the following:

- Fire and smoke compartmentation of the patient care areas, in particular the Wards.

- Installation of two (2) smoke exhaust fans, one at the east end of the building and one at the west end of the building. These exhaust fans serve Levels 2 through 5.

- Upgrade of the smoke control system to enable zone smoke control, or zone pressurisation. The zone pressurisation is based on floors, not fire or smoke compartments.

The work undertaken during this refurbishment forms the basis for fire and smoke compartmentation as it now exists in the hospital, and as shown in Figures 4.1 – 4.5 in Section 4.4.2.

Level 4 and Level 5 are divided into two fire compartments, East and West, as shown in Figure 4.9. A dedicated mechanical services riser serves each fire compartment. The mechanical services riser contains an exhaust duct, being the return air for the air-conditioning which was used as smoke exhaust in a fire event.

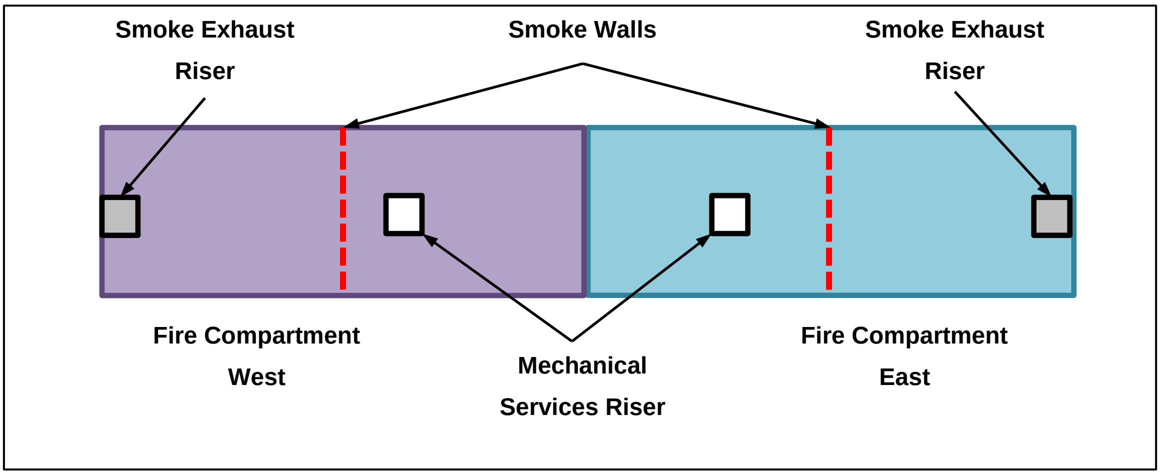

Figure 4.9: Levels 4 and 5 Compartmentation Schematic (plan)

The ward areas of Level 2 and Level 3 are of similar layout to Level 4, with two fire compartments, East and West, with a fire compartment between them, encompassing the lift lobby and Dental Services. Level 3 also contains the Operating Theatre Plant Room, which is divided into two separate fire compartments. The Level 3 plant room contains the AHUs for the Operating Theatres on Level 2, as well as AHUs serving the Central Fire Compartment of Level 3.

Two small fire compartments containing communication equipment are also located on Level 3. It is unclear whether or not these communications fire compartments were part of the original construction or not, but from the construction of the fire walls in these areas it would appear they are a later addition. Regardless, they do not influence the smoke control strategy for the patient care areas on this level, and are not considered in the following assessment of smoke control. Figure 4.10 shows a schematic of the fire compartment layout.

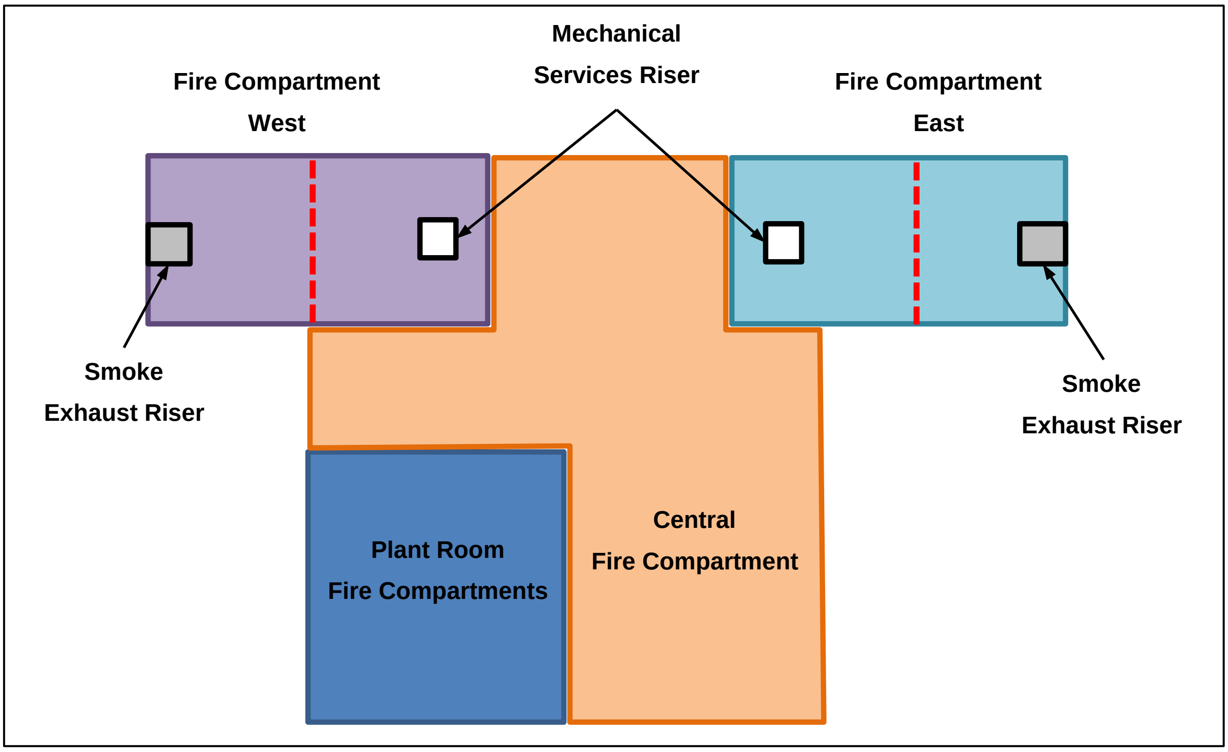

Figure 4.10: Level 3 Compartmentation Schematic

In addition to the East and West Fire Compartments, Level 2 contains the Operating Theatres, which are in a single fire compartment, and the Emergency Department, which form part of a Central Fire Compartment, along with the lift core and some allied health services.

Figure 4.11, below, shows the layout of the fire compartments on Level 2, which is essentially the same as Level 3.

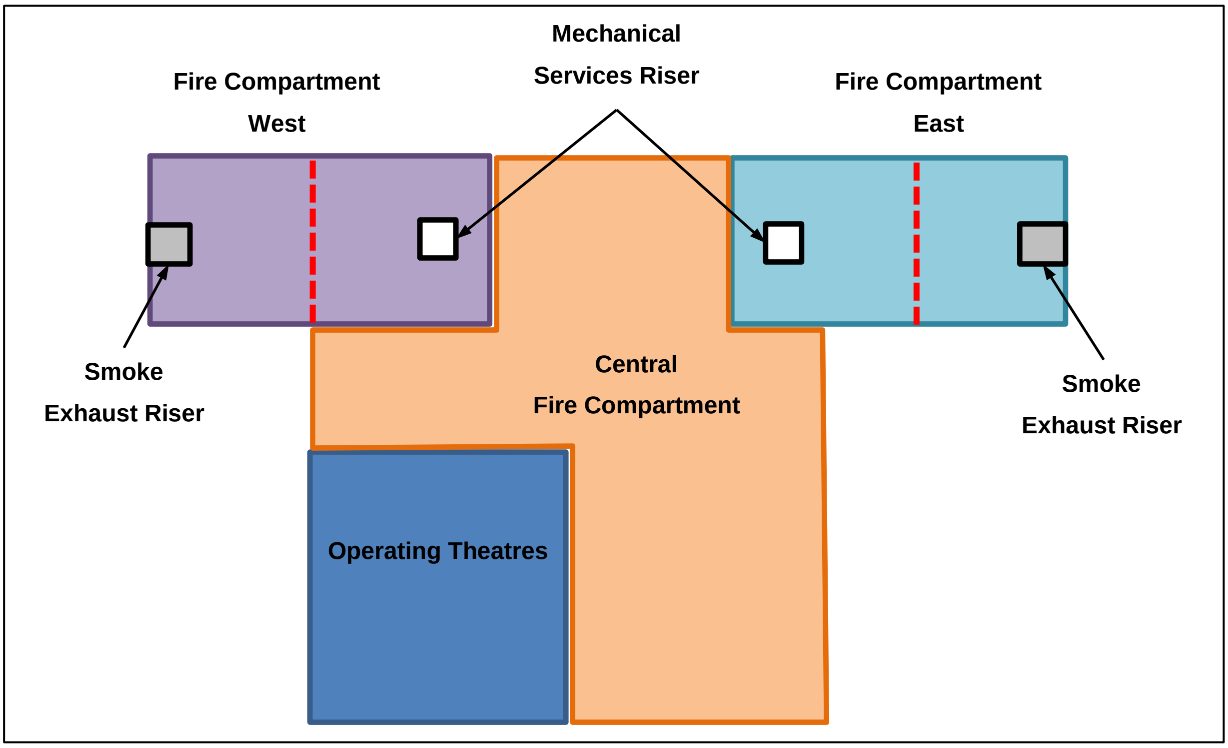

Figure 4.11: Level 2 Compartmentation Schematic

In the original construction the Out Patients Department on Level 1 was smaller than the present Out Patients Department, but still fire separated from the Hospital Reception and Cafeteria area that, along with allied health services, makes up the majority of Level 1. Medical Records is a separate fire compartment again, and although it has had its smoke exhaust system upgraded appears to have been part of the original construction. Figure 4.12, below, shows the schematic layout of the fire compartments on Level 1. Small plant rooms on Level 1 contain air-handling equipment for Medical Records and Out Patients Department, as well as the kitchen and cafeteria.

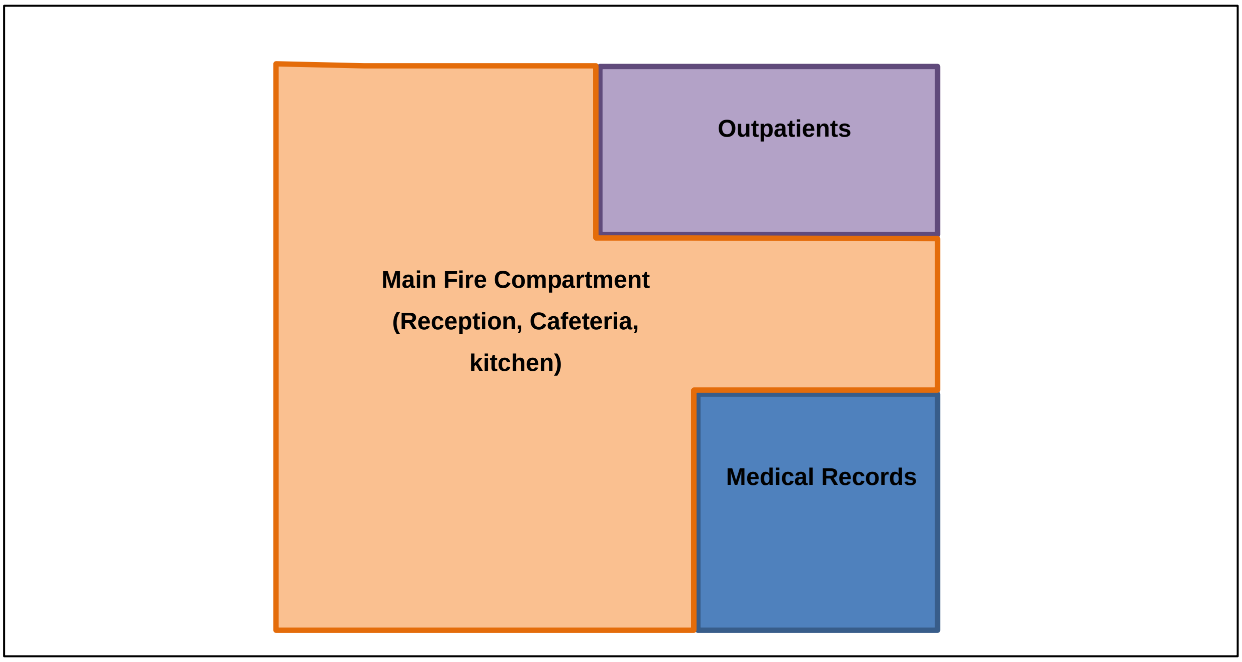

Figure 4.12: Level 1 Compartmentation Schematic

As stated above, the smoke control strategy adopted following the 1996 refurbishment is one of Zone Pressurisation based on Levels. This is enabled by the two (2) mechanical risers serving all levels of the hospital. Figure 4.13 shows a schematic of the smoke control arrangements for a fire event on a typical level. The schematic shows the fire level as being Level 4, with Levels 3 and 5 being shown. For clarity, only the exhaust air path and associated motorised dampers are shown in the schematic.

The smoke control philosophy is summarised as follows:

- Smoke detection activates on fire affected level.
- Supply air dampers to the fire affected floor close.
- Supply air dampers to non-fire affected floors remain fully open.
- Fire and smoke doors on the fire affected floor close.
- Motorised dampers in smoke walls, located in the ceiling plenum, on the fire affected compartment close. Note that dampers in the smoke wall of the non-fire affected compartment on the fire affected level remain open.
- Outside air dampers on AHUs moves to fully open, supplying 100% outside air to non-fire affected floors.

– Return air dampers on fire affected floor remain open, providing a smoke spill path through the ceiling plenum to atmosphere above the roof, via the mechanical riser.

– Motorised dampers in the smoke exhaust riser open on the fire affected floor, providing a smoke spill path through the ceiling plenum to atmosphere above the roof, via the smoke exhaust riser.

– Return air dampers on non-fire affected floor close, pressurising these levels.

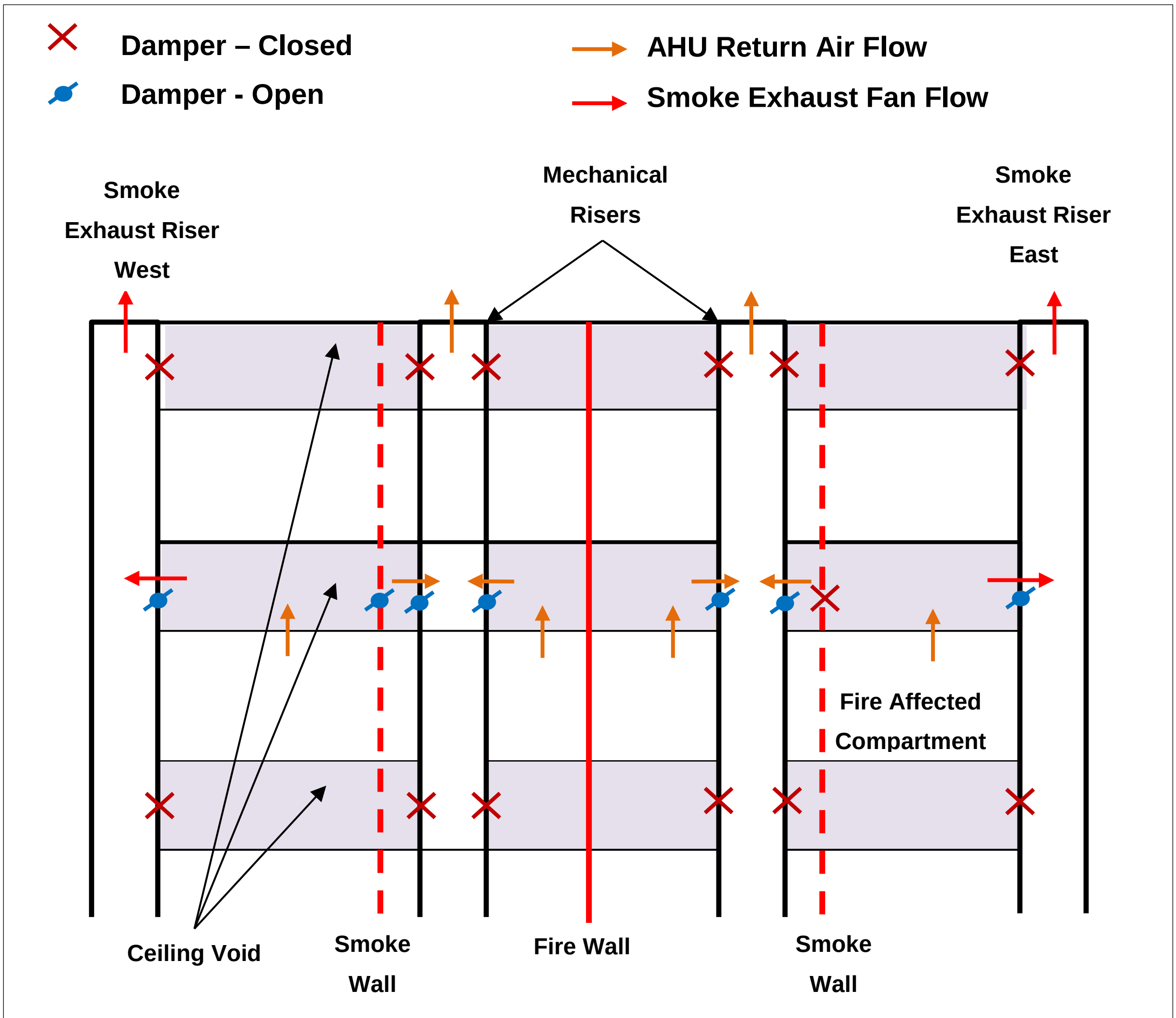

Figure 4.13: Smoke Exhaust Schematic – 1996 Refurbishment

The upgrade to the smoke hazard management system associated with the 1996 hospital refurbishment was designed to convert the smoke control to a zone pressurisation system, operating on a level by level basis. The upgrade saw the following additions and alterations to the existing smoke control:

1. Two smoke exhaust fans were added to Level 6 of the hospital.

2. Two smoke exhaust risers servings Levels 2, 3, 4 and 5, one located adjacent to the western fire stair shaft, the other adjacent the eastern fire stair shaft.

3. Motorised dampers were added to the smoke exhaust risers at each level served.

4. Fire and smoke were constructed in the Ward areas of Level 2, Level 3, Level 4 and Level 5, creating two fire compartments on each level, with each fire compartment containing two smoke compartments.

These upgrades were designed to allow a transition to a zone pressurisation system in accordance with AS/NZS 1668.1.

The smoke exhaust fans, each with a nominal capacity of 7.5 m^3/s were designed to extract 6 m^3/s of exhaust from the fire affected floor. The smoke control system would have been designed to AS/NZS 1668.1 1991 [16] which was in force in 1996. In addition to a performance criteria stipulating not less than 20 Pa positive pressure developed in all non-fire affected compartments (in relation to the fire affected compartment) this standard requires that:

> *Where a smoke-spill fan is employed to remove smoke from the fire affected compartment, it shall have an exhaust capacity providing for air leakage though other dampers on non-fire floors, and the greater of –*
>
> a) Not less than six air changes per hour for the largest compartment served; or
>
> b) Not less than the volume of make-up air entering the largest compartment when all required exit doors serving that floor are open, and make-up air through the exits enters the compartment.

With two required exits from the Ward fire compartments, one single leaf door 0.9 m wide and one double door 1.8 m wide an area of 5.2 m^2 is available for make-up air to enter the compartment with the exit doors open. Using the advised velocity of 2 m/s for make-up air through doors this gives 10.4 m^3/s of exhaust. The installed 12 m^3/s of smoke exhaust for the fire compartment allows for the make-up air through doors, with 1.6 m^3/s above this requirement to account for air-leakage through other dampers. The smoke exhaust requirements appear to be designed correctly to meet AS/NZS 1668.1 1991 [16].

The primary performance requirement for an AS/NZS 1668.1 1991 zone pressurisation system, given in Clause 5.8.2, is:

A positive pressure of not less than 20 Pa shall be developed in all non-fire affected compartments above the pressure in the fire-affected compartment, measured with all doors closed to required exits.

This design exhausts both fire compartments on Level 4 and Level 5 when either of these is the fire affected floor. It also exhausts a minimum of two (2) fire compartments on each of Level 2 and Level 3 should either of these floors go into fire alarm. Under this arrangement the primary performance requirement for a zone pressurisation system cannot be met in this building.

Level 4 and Level 5 pose another problem with this arrangement. There are only two (2) fire compartments on each of these levels, so in fire alarm the entirety of the fire affected floor is being exhausted. Two corridors run the full length of the building on each of these levels. The fire wall between the two fire compartments contains two double leaf doors aligned with the corridors. The doors are on magnetic hold open devices that release the door on fire alarm, and each door is hinged to swing in both directions. Under the 1996 design, with both fire compartments exhausting, an imbalance in the exhaust rate between compartments, which is considered very likely, may result in smoke migrating into the non-fire affected compartment as it flows towards the lower pressure.

While the 1996 upgrade to the smoke hazard management system has changed the smoke control philosophy to one of zone pressurisation, the implementation of the zone pressurisation documented fails to achieve the primary performance criteria for a zone pressurisation system. This upgrade to the smoke control system does not appear to have improved the overall performance of the smoke control system.

4.5.3. 2008 Extensions to Emergency Department and Operating Theatres

In 2008 – 2009 extensions to the Emergency Department and Operating Theatres on Level 2, the Out Patients Department on Level 1 and a refurbishment of the Level 5 Wards was undertaken. This work involved changes to the smoke hazard management system in the Out Patients area of Level 1 and the Operating Theatres on Level 2.

As these works involved a number of minor non-compliances to the BCA a Fire Engineering Report (FER) [11] was produced. The outcomes of this FER include a section on smoke hazard management. The FER notes the following in this regard:

Existing smoke detection system shall be retained and extended throughout all refurbished and new areas in accordance with the BCA DTS requirements.

> *Existing zone smoke control system shall be retained and extended throughout all refurbished and new areas in accordance with the BCA DTS requirements.* [11]

This is reasonably standard wording to provide higher level guidance to the mechanical consultant for his/her smoke hazard management design. Indeed, it appears that this guidance has been followed in the design, and implemented into the building.

Commissioning, however, appears to be lacking, with no records to indicate that the system was commissioned and found to meet the requirements of the FER and AS/NZS 1668.1 1998. For instance, while the smoke hazard management system works well within the new Out Patients Department, there is no record of how it achieved 20 Pa positive pressure compared to fire affected compartment when the fire was located in the neighbouring compartment, which has no smoke exhaust. It is also unclear how the commissioning could have passed the modified smoke hazard management in the Operating Theatres, which shut down the air-handling equipment for the wrong theatre in some cases.

4.6. SMOKE EXHAUST CALCULATIONS

While the primary purpose of smoke exhaust in an AS/NZS 1668.1 zone pressurisation system is not for occupant safety in the fire affected compartment, it is an interesting exercise to determine whether or not smoke exhaust designed to meet AS/NZS 1668.1 is capable of maintaining tenability to enable occupant egress. To gauge the veracity of the installed Smoke Exhaust within the Level 2 to Level 5 Wards of the hospital hand calculations will be undertaken. As stated in Section 4.5.1, it has been surmised that the original smoke exhaust strategy consisted of smoke exhaust via the return air of the air-conditioning system. As the details of the original air-conditioning system have not been able to be sourced by the author, the smoke exhaust calculation will be done on the smoke control system as modified in 1996 – 1997. This smoke control system forms the basis of the current smoke control methodology for the Level 2 to Level 5 Wards in the hospital today.

The following is known about the compartment and smoke exhaust system being studied:

1. The designed smoke exhaust rate per fire compartment is 12 m^3/s. This is further broken down to $6 m^3/s$ per smoke compartment.

2. Smoke exhaust is through a ceiling plenum, to an exhaust duct located at the extremity of the building, and up through a fire isolated shaft to a roof mounted exhaust fan.

3. The ceiling height in the ward areas is 2.7 m, with an 800 mm ceiling void giving a 3.5 m total compartment height.

4. Air-conditioning on the fire affected floor goes into full outside air mode, and the return air acts as smoke exhaust, providing 6 m^3/s per compartment.

5. The design intent at the time of installation was for Air-conditioning to shut down on the entire fire affected floor, with both smoke exhaust systems being activated and exhausting this level.

6. Air-conditioning Return Air dampers are closed on all other levels, over-pressurising these compartments.

To enable the smoke exhaust rate calculations the following assumptions have been made:

1. The design area for the smoke exhaust quantity was based on a single smoke compartment on each level, i.e. approximately 500 m^2.

2. The BCA DTS design fire steady state maximum of 5 MW as indicated in Specification E2.2b was used for calculation of smoke exhaust rates. This design fire size has not changed since the 1996 edition of the BCA.

3. The total height of the compartment, from finished floor level (FFL) to underside of slab above is approximately 3.5 m on each level.

4.6.1. Design Fire

To determine the smoke exhaust requirements for a compartment, a design fire must be established. The BCA provides guidance of design fire size for smoke exhaust calculation in both sprinklered and non-sprinklered buildings, via Specification E2.2b. For the calculations a fire with a Fast t^2 growth rate peaking at 5 MW will be used, as shown in Figure 4.14.

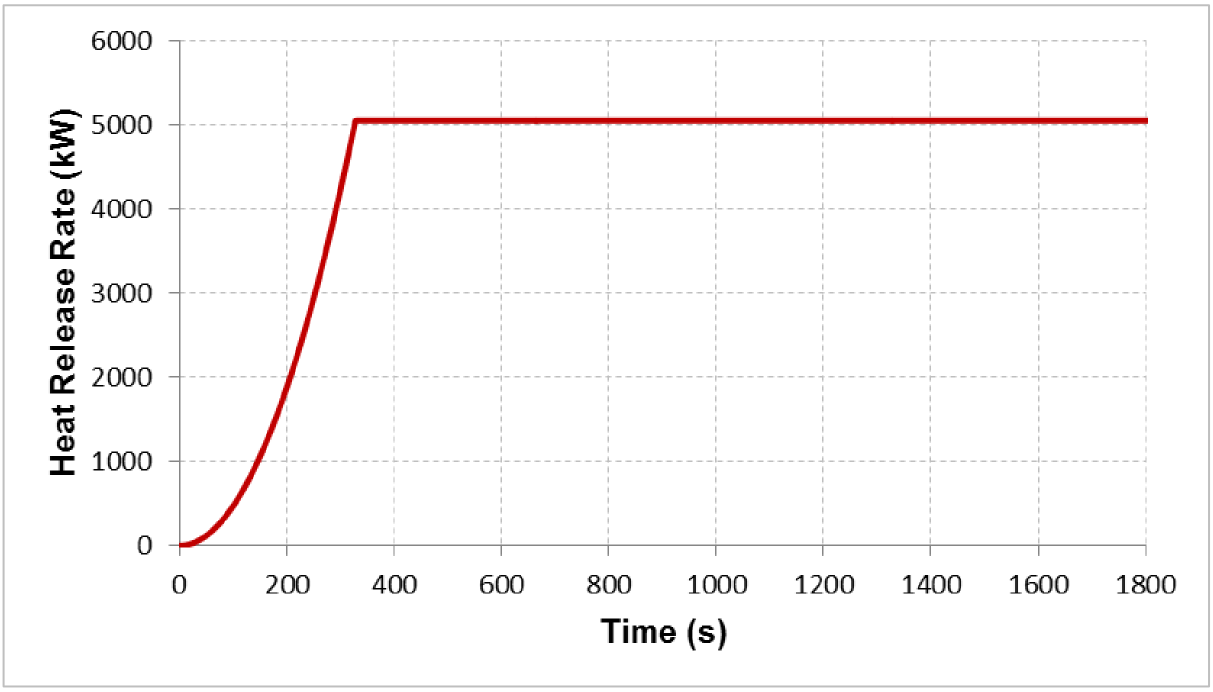

Figure 4.14: Design Fire HRR Curve

4.6.2. Rate of Smoke Mass Production – Axisymmetric Plume

An axisymmetric plume will be assumed for the calculation of the rate of smoke mass production. The Guide to the BCA 2011 [1] states that the smoke exhaust rate in Figure 2.1 of Specification E2.2b is based on 'the rated at which air is drawn (i.e. entrained) into a plume of smoke which is generally symmetrical around a vertical axis where that plume is rising into the hot layer…' Therefore, an axisymmetric plume is considered appropriate for these calculations.

Firstly, NFPA 92 2012 Equation 5.5.1.1d is used to find the limiting elevation:

$$z_l = 0.166\dot{Q}_c^{2/5}$$ **Equation 1**

Where:

$z_l =$ limiting elevation (m)

$\dot{Q}_C =$ convective portion of the heat release rate (kW)

The convective portion of the heat release rate is calculated using NFPA 92 2012 Equation 5.5.1.3:

$$\dot{Q}_C = \chi\dot{Q}$$ **Equation 2**

Where:

$\dot{Q}$ = heat release rate (kW)

χ = convective fraction

As stipulated in NFPA 92 2012, the convective fraction will be taken as 0.7.

$\dot{Q}_C = 0.7 \times 5{,}000$

$\dot{Q}_C = 3{,}500$ kW

$z_l = 0.166 \times 3{,}500^{2/5}$

$z_l = 4.35$ m

The limiting elevation is used to determine the method of calculation for the mass flow rate using NFPA 92 2012 Equations 5.5.1.1e and 5.5.1.1f, as follows:

$when\, z > z_l, \dot{m} = \left(0.071\dot{Q}_c^{1/3} z^{5/3}\right) + 0.0018\dot{Q}_c$ **Equation 3**

$when\, z \leq z_l, \dot{m} = 0.032\dot{Q}_c^{3/5} z$ **Equation 4**

The design height for the smoke layer is assumed to be 2.7m, keeping the smoke layer in the ceiling plenum. As this is below the limiting height calculated above, Equation 4 will be used to calculate the mass flow rate in the plume at 2.7m:

$\dot{m} = 0.032 Q_c^{3/5} z$ **Equation 5**

Where:

$\dot{m}$ = mass flow rate in plume at height z (kg/s)

$\dot{Q}_C$ = convective portion of the heat release rate (kW)

z = distance above the base of the fire to the smoke layer interface (m)

$\dot{m} = 0.032 \times 3{,}500^{3/5} \times 2.7$

$\dot{m} = 11.6$ kg/s

4.6.3. Smoke Layer Temperature

The average smoke layer temperature is calculated using NFPA 92 2012 Equation 5.5.5:

$T_s = T_0 + \frac{K_s Q_C}{\dot{m} C_p}$ **Equation 6**

Where:

T_s = smoke layer temperature (°C)

T_0 = ambient temperature (°C)

K_s = fraction of convective heat release contained in smoke layer

Q_c = convective portion of heat release rate (kW)

m = mass flow rate of the plume at elevation z (kg/s)

C_p = specific heat of gas plume (kJ/kg-°C)

As stated in NFPA 92 2012 the smoke layer shall be assumed to contain 100% of the convective portion of heat release, and so the convective portion of heat release will be taken as 1. The ambient temperature for air-conditioned buildings is taken as 24°C, and the specific heat of the gas plume is taken as 1.0 kJ/kg-°C, giving:

$$T_s = 24 + \frac{3,500}{11.6}$$

$$T_s = 326 \text{ °C}$$

4.6.4. Smoke Density

To find the volumetric flow rate, we must first determine the smoke density. Smoke density is calculated using Equation 5.8b from NFPA 92 2012:

$$\rho = \frac{P_{atm}}{RT} \qquad \textbf{Equation 7}$$

Where:

$\rho =$ density of smoke at temperature (kg/m^3)

P_{atm} = atmospheric pressure (Pa)

R = gas constant (287)

T = absolute temperature of smoke (K)

$$\rho = \frac{101,325}{287 \times 599}$$

$$\rho = 0.589 \text{ kg/m}^3$$

4.6.5. Volumetric Flow Rate

The volumetric flow rate of smoke exhaust is now calculated using Equation 5.7b from NFPA 92 2012:

$$V = \frac{m}{\rho}$$ **Equation 8**

Where:

$V =$ volumetric flow rate of smoke exhaust (m^3/s)

$m =$ mass flow rate of smoke exhaust (kg/s)

$\rho =$ density of smoke (kg/m^3)

$$V = \frac{11.6}{0.589}$$

$$V = 20 \text{ m}^3/\text{s}$$

From this figure, it can be seen that the smoke exhaust rate provided, i.e. 12 m^3/s, while complying with AS/NZS 1668.1 1991 requirements, will not keep smoke above the ceiling level, thereby providing safe conditions for evacuation.

4.7. MODELLING – BRANZFIRE

As a backup to the calculations above, BRANZFIRE 2012.1 [17] has been used to run some simple fire scenarios to determine if the installed smoke exhaust will provide sufficient extraction to maintain the smoke layer at the design height.

The computer program BRANZFIRE (Version 2012.1) is a zone fire model which can be used to calculate the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire. This program was produced by the Building Research Association of New Zealand (BRANZ) and the University of Canterbury.

BRANZFIRE is a computer program that utilises a two zone model approach, which can accommodate up to 10 compartments, where each compartment is divided into two (2) separate zones (i.e. an upper layer of hot gaseous products of combustion and a lower cooler layer). Each layer is assumed to be homogeneous.

4.7.1. Modelling of Original Construction

As explained in Section 4.5.1, the original construction used a floor-by-floor pressurisation system. Level 4 has been modelled as the fire affected floor. A single room modelled, measuring 20 m x 1000m, giving a total floor area of 2000 m^2. T Two window openings, each measuring 1.2m wide by 1.0 m high as representative of two windows in a four bed room in a ward, provide ventilation to room of fire origin. Wade and Robbins [18] in their work on smoke filling in large spaces using BRANZFIRE indicate that a Zone Model such as BRANZFIRE is best used to model compartments up to 1,200 m^2 in area. As part of the study, Wade and Robbins compared a 25 m x 100m (2,500m^2) single room BRANZFIRE model to FDS model results of the same room. It was found that for this case the zone model predictions for average upper layer temperatures were within the range of upper layer temperatures predicted by FDS. Further, it was found that the zone model predicts a slower initial descent of the layer, but is ultimately closer to the floor at a later stage. [18] Therefore, it is considered that, for the modelling to be conducted for this report, the use of a single room zone model of 2,000 m^2 in area will provide acceptable results.

Four Scenarios were run, each using the design fire developed in Section 4.6.1. The model was run with two different fuel types, wood and flexible polyurethane foam, as representative of fuel types Each fuel type was modelled with 12 m^3/s and 20 m^3/s of exhaust, to determine where the smoke layer was held by the both the smoke exhaust installed and the smoke exhaust calculated as required in Section 4.6.

The exhaust fans were mounted at 3m above finished floor level, as the exhaust ducts are in the hospital. Table 4.3, below, shows the parameters used for each model run. Two fuel types have been used, wood and flexible polyurethane foam. The default properties for each fuel type contained in BRANZFIRE have been used, with the exception of the mass loss rate. BRANZFIRE requires a representative mass loss rate per unit area to be specified to determine the diameter of the fire only and for use in the Dilichatsios plume model. This value does not affect the heat release rate, nor does it affect the mass loss rate determined by the program from the heat release rate and energy yield values entered. [19] Values for mass loss rate have been used as follows:

a) Wood (Douglas Fir): 0.013 kg/m^2 s [20]

b) Flexible Polyurethane Foam: 0.021 kg/m^2 s [21]

The materials modelled consist of a concrete ceiling and roof, and plasterboard (Australia) walls. Material properties are from the materials database in BRANZFIRE, and have not been altered. Environmental conditions have been modelled as follows:

a) Ambient temperature – internal: 24°C (air conditioning operating)

b) Ambient temperature – external: 35°C (a hot summers day in Brisbane)

c) Relative humidity 50% (internal with air conditioning)

For all fire scenarios the fire base has been placed at floor level.

Time of tenability is based on the earliest time that any End-Point Conditions is reached. The End-Point Conditions, based on those presented in the Fire Engineering Design Guide [22] are:

1. Fractional Effective Dose (FED) Narcotic Gases – 0.3.
2. FED Thermal – 0.3.
3. Upper Layer Temperature – 200°C.
4. Visibility at 2 m above finished floor level – 10 m.
5. Temperature at 2 m above finished floor level – 60°C.

Table 4.3: BRANZFIRE Modelling Parameters

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Mechanical Venting (m^3/s)	12	20	12	20
Fire type	Fast t^2	Fast t^2	Fast t^2	Fast t^2
Fuel type	Polyurethane Foam	Polyurethane Foam	Wood	Wood
Soot Yield (kg/kg)	0.227	0.227	0.015	0.017
Energy Yield (kJ/g)	19	19	12.4	12.4
Radiant Loss Fraction	0.3	0.3	0.3	0.3
Mass loss rate ($kg/s.m^2$)	0.021	0.021	0.013	0.013
Air entrainment	McCaffery	McCaffery	McCaffery	McCaffery
Ceiling Jet model	Alpert	Alpert	Alpert	Alpert

4.7.2. Model Results

Table 4.4 summarises the End-Point Conditions in the room of fire origin for each Scenario modelled. Input/output Summaries for each Scenario can be found in Appendix C.

The minimum end point condition for each scenario is reached at approximately 470 seconds for each scenario, and in each case it is the visibility and temperature at 2m above finished floor level that are reached first. This suggests that the time to reach the visibility limit and temperature limit are not greatly affected by the type of fuel or the exhaust quantity.

Table 4.4: End Point Conditions

End-Point Condition	Time End-Point Condition Reached (s) in room of fire origin			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
FED Narcotic Gases	855	859	738	740
FED Thermal	594	594	577	577
Upper Layer Temperature	Not Reached	Not Reached	Not Reached	Not Reached
Visibility at 2m	473	473	467	468
Temperature at 2m	473	473	467	468
Minimum Endpoint Condition	**473**	**473**	**467**	**468**

A graph showing layer height for the four scenarios modelled is shown in Figure 4.15, with the layer temperature shown in Figure 4.16.

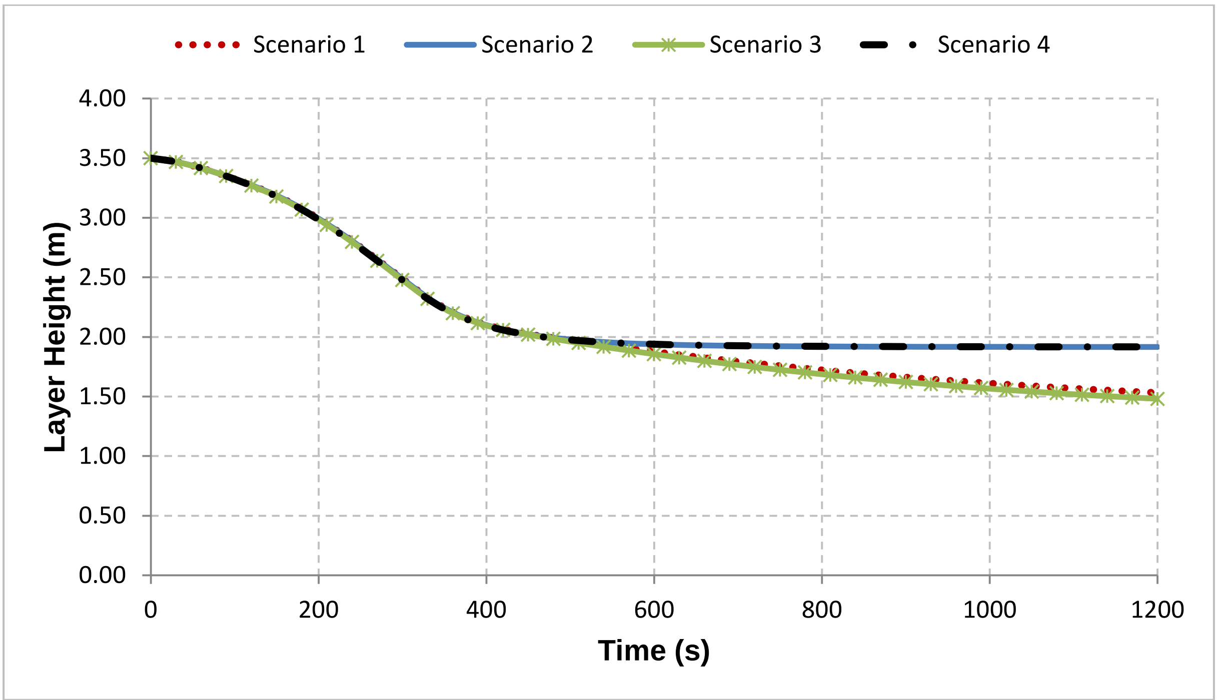

Figure 4.15: Comparison of Layer Heights

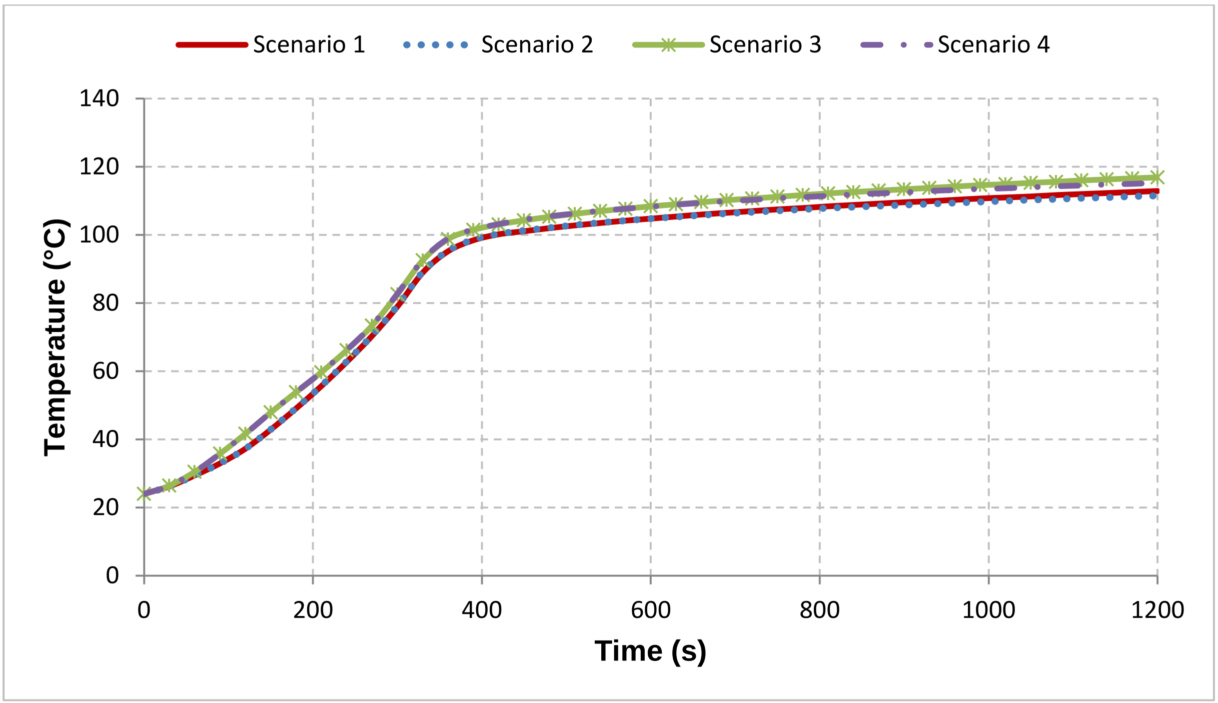

Figure 4.16: Comparison of Layer Temperatures

It can be seen from the layer height graph that the 20 m^3/s of smoke exhaust, as expected, maintains the smoke layer at a greater height that the 12 m^3/s of exhaust. Indeed, the smoke layer is still descending at 1,200 seconds when the modelling completes with the smaller exhaust rate. From the graph of layer temperature it can be seen that the wood fuel gives a higher temperature in the smoke layer that the flexible polyurethane foam, and as expected, the higher smoke exhaust rate provides a reduction (albeit a small reduction) in smoke layer temperature for both fuel types.

4.7.3. Modelling of Post 1996 Refurbishment

As explained in Section 4.5.2, the 1996 hospital refurbishment added fire and smoke compartmentation to the Wards, particularly on Levels 3, 4 and 5. Level 4 has been modelled as the fire affected floor. Two rooms were modelled, measuring 20 m x 25 m, giving a total floor area of 1000 m^2. The two compartments will be connected by two 6 mm wide x 2 m high openings, representing the leakage through two double leaf smoke doors. Two window openings, each measuring 1.8 m wide by 1.0 m high as representative of two windows in a four bed room in a ward, provide ventilation to room of fire origin.

As was the case for the original construction, four scenarios were run, each using the design fire developed in Section 4.6.1, to determine where the smoke layer was held by the both the smoke exhaust installed and the smoke exhaust calculated as required in Section 4.6.

The model setup is as described in Section 4.7.1. Table 4.5 shows the BRANZFIRE modelling parameters used.

Table 4.5: BRANZFIRE Modelling Parameters

Parameter	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Mechanical Venting (m^3/s)	6 (per smoke compartment)	20	6 (per smoke compartment)	20
Fire type	Fast t^2	Fast t^2	Fast t^2	Fast t^2
Fuel type	Polyurethane Foam	Polyurethane Foam	Wood	Wood
Soot Yield (kg/kg)	0.227	0.227	0.015	0.017
Energy Yield (kJ/g)	19	19	12.4	12.4
Radiant Loss Fraction	0.3	0.3	0.3	0.3
Mass loss rate ($kg/s.m^2$)	0.021	0.021	0.013	0.013
Air entrainment	McCaffery	McCaffery	McCaffery	McCaffery
Ceiling Jet model	Alpert	Alpert	Alpert	Alpert

4.7.4. Model Results

Table 4.6 summarises the End-Point Conditions in the room of fire origin for each Scenario modelled. Input/output Summaries for each Scenario can be found in Appendix C.

The minimum end point condition for each scenario is reached at approximately 470 seconds for each scenario, and in each case it is the visibility and temperature at 2m above finished floor level that are reached first.

Table 4.6: End Point Conditions

End-Point Condition	Time End-Point Condition Reached (s)			
	Scenario 5	Scenario 6	Scenario 7	Scenario 8
FED Narcotic Gases	492	655	444	549
FED Thermal	287	346	282	342
Upper Layer Temperature	390	1103	366	699
Visibility at 2m	221	325	221	323
Temperature at 2m	221	325	221	323
ASET (s) (i.e. minimum endpoint condition)	**221**	**325**	**221**	**323**

A graph showing layer height in the room of fire origin for the four scenarios modelled is shown in Figure 4.17, with the layer temperature in the room of fire origin shown in Figure 4.18.

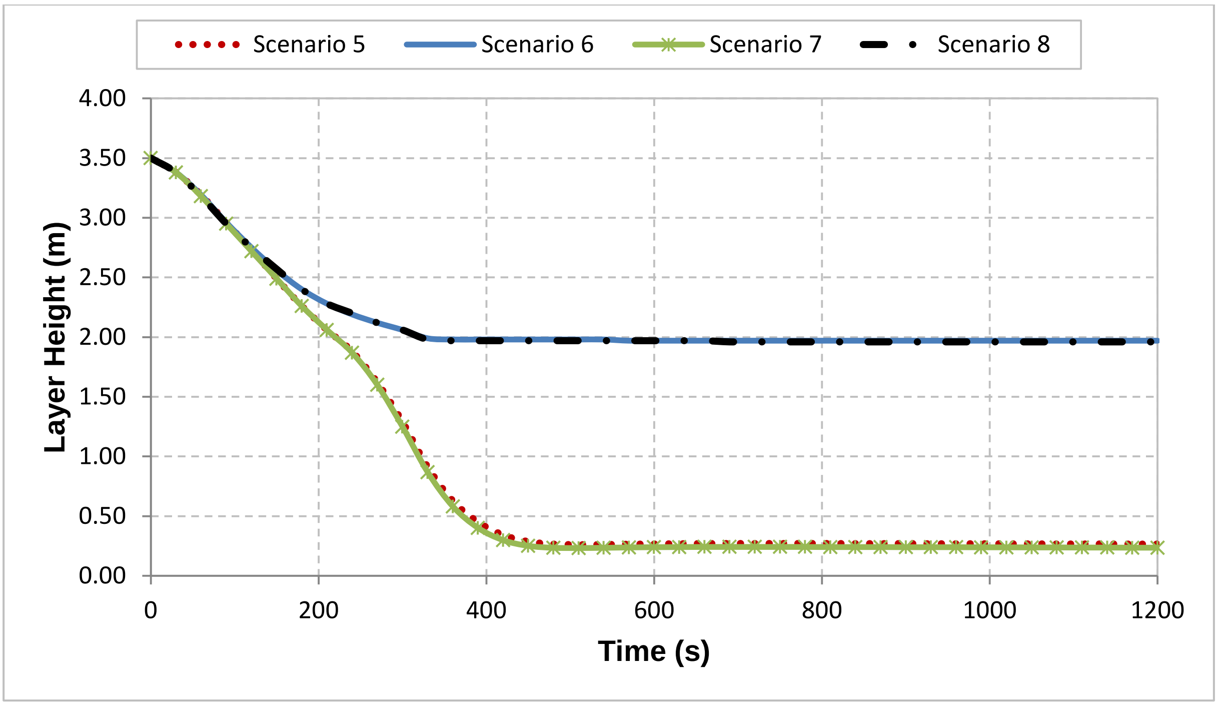

Figure 4.17: Comparison of Layer Heights

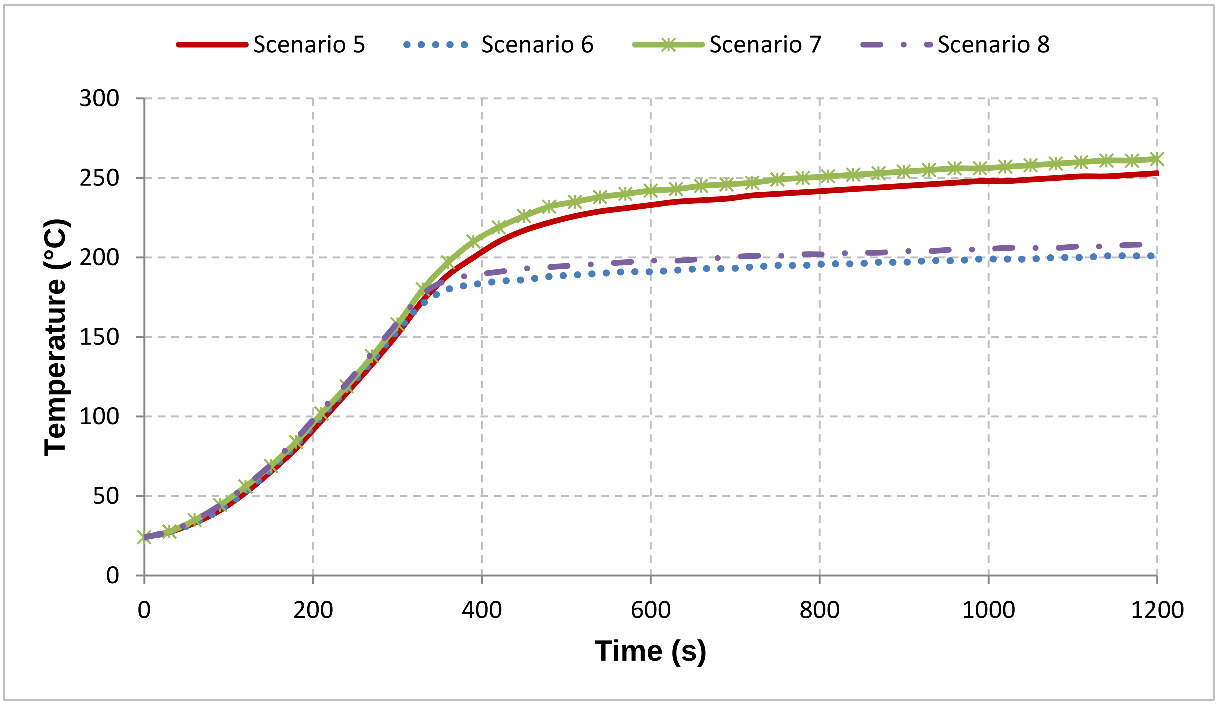

Figure 4.18: Comparison of Layer Temperatures

Again, as expected, 20 m^3/s of exhaust maintains the smoke layer at a greater height that the 12 m^3/s of exhaust, at approximately 1.96 m for the greater exhaust rate and 0.25 m for the lesser exhaust rate. Results from the temperature graph are similar to those achieved with the original construction, but higher in each case.

Results for Room 2 have not been shown, as the upper layer did not descend in this room, indicating minimal smoke flow between the rooms.

4.7.5. Modelling Summary

From a direct comparison of the minimal end point conditions it would appear that the original construction and smoke system gives a better result, with longer times until untenable conditions are reached in the fire compartment. However, this straight comparison ignores the compartmentation issue. The smoke and fire compartmentation restrict the spread of smoke and fire throughout the floor, with only a single smoke compartment affected by fire in the post 1996 modelling, as opposed to floor wide smoke spread in the original construction.

It should be noted that the BRANZFIRE modelling of the post 1996 compartmentation assumes that the smoke and fire walls are well constructed, and will prevent fire the spread of fire and/or smoke. Additionally, in the modelling only the smoke compartment of fire origin has been exhausted. In Hospital A, it is suggested in Section 4.8 of this report that the fire and smoke walls are in disrepair and while they will restrict the spread of fire and/or smoke, they will not prevent such spread for time frames the required FRLs would suggest.

Smoke exhaust in Hospital A is not strictly as modelled (or as suggested in AS/NZS 1668.1 1998 [2]) in that fie compartments are sent into exhaust on a fire alarm, not smoke compartments. This leads to the possibility of smoke spread to the neighbouring smoke compartment caused by the smoke exhaust system.

For these reasons it is not possible to say that the modelling has demonstrated an improvement in the smoke control system post the 1996 refurbishment and smoke control upgrade.

4.8. SMOKE HAZARD MANAGEMENT SYSTEM REVIEW – 2011

In 2011/2012 Consultant A undertook a review of the smoke hazard management system in Hospital A. The scope of this review was to ascertain the current operational status of the smoke control provisions, mechanical air-handling system and fire alarm zoning.' [15] The review included:

- A desktop review of the mechanical system and fire alarm system.
- A visual check of the fire and smoke walls, including penetrations.
- A visual check of location of dampers.
- Testing of the smoke hazard management system on each level of the hospital.

- Production of a cause and effect matrix for the fire system.

Over a period of four months consultants undertook periodic site visits to Hospital A to undertake visual checks and fire system testing. The review highlighted some problems with the smoke hazard management system as installed, and these are presented in the following sections, taken from an audit report [23] and smoke control report [15] produced by Consultant A following completion of the smoke hazard management system review.

4.8.1. Fire and Smoke Walls

In a zone pressurisation system in a health care building, properly installed and maintained fire and smoke walls play an important role in the prevention of fire and smoke spread from the compartment of fire origin. This is particularly so in the case of Hospital A, as there are no sprinklers installed within the building.

A visual inspection only of the fire and smoke walls was undertaken, with no destructive inspection allowed. Generally the standard is recorded as poor. The following faults are listed in Consultant A's report:

1. There appears to be no lapping, or incorrect, lapping of the fire rated plasterboard where the walls change direction or abut concrete columns.

2. Screw heads have not been covered with fire rated sealant as required by the manufacturer's installation guidelines.

3. Cable and pipe penetrations have not been sealed with a fire rated mastic, leaving holes through the walls.

4. Cable trays and fire dampers are not framed in the wall as required by the fire rated plasterboard manufacturer's installation guidelines.

5. Large holes in the fire wall surrounding the Operating Theatres were detected.

6. No up to date penetration register was able to be located.

The report concludes that the current state of the fire and smoke walls is poor, with the required Fire Resistance Level (FRL) of the walls not being achieved. As a result fire and smoke spread throughout the building will be to quicker than should be the case, with attendant life safety risks. The report recommends a priority maintenance program be undertaken to rectify faults found to restore the walls to the required FRL. [15]

4.8.2. Level 1 Review Outcomes

The Level 1 fire systems were tested, with a smoke detector in each fire compartment being activated and trace smoke being used in the compartment in fire alarm to determine airflows. The following was noted during the testing:

1. Detection zones do not appear to have been updated to reflect the changing fire compartments.

2. There is no smoke exhaust in the main area of Level 1.

3. Out Patients fire compartment has dedicated Air-Handling Units (AHU) and smoke spill fans for each smoke compartment. Smoke hazard management in this area operates as per a zone pressurisation system.

4. Medical Records fire compartment has dedicated AHU and smoke spill fans. Smoke hazard management in this area operates as per a zone pressurisation system.

The Out Patients Department operates as a full zone pressurisation system, but with no commissioning data and no exhaust in the neighbouring fire compartment a pressure test is required to determine that the requirement for a 20 Pa pressure differential has been met, i.e. the Out patients Department does not seem to have been integrated into the existing smoke control system.

4.8.3. Level 2 Review Outcomes

The Level 2 fire systems were tested in the same manner as the Level 1 fire systems. The following was noted during the testing:

1. Detection zones do not appear to have been updated to reflect the changing fire compartments.

2. Smoke Exhaust Fan West (SEF-West) operates on a fire event in the fire compartment containing West Ward.

3. Smoke Exhaust Fan East (SEF-East) did not operate on a fire event in the fire compartment containing East Ward.

4. Activation of smoke detection in the Emergency Department demonstrated some fire/ smoke doors closed. The air-conditioning did not shut down.

5. Operating Theatre Compartment 2.6 was reviewed prior to surgery commencing, and the detectors in the corridors were checked first. The southern corridor detector

operated Theatre 7 smoke control systems – not Compartment 2.6 – programmed for the wrong compartment.

6. Tested the Operating Theatre northern corridor smoke detection and this shut down the corridor A/C systems. Theatres were at negative pressure.

As with Level 1, the smoke control in the Operating Theatres was upgraded in 2008. It would appear that commissioning has not been correctly carried out, resulting in incorrect activation of smoke exhaust in this area. Coupled with the poorly maintained fire walls this represents a risk to life safety in the event of a fire.

4.8.4. Level 3 Review Outcomes

1. The Level 3 fire systems were tested in the same manner as the Level 1 fire systems. The following was noted during the testing:

2. Detection zones do not appear to have been updated to reflect the changing fire compartments.

3. SEF-West operates on a fire event in the West Ward fire compartment.

4. SEF-East operates on a fire event in the East Ward fire compartment.

5. No smoke exhaust operates on a fire alarm in the Main Floor.

6. Fire and smoke doors all close on fire alarm in any zone.

This represents a partial zone smoke control system, with not all compartments being exhausted. Commissioning has failed to pick up the inconsistent zoning of the smoke detection system.

4.8.5. Level 4 Review Outcomes

The Level 4 and Level 5 fire systems were tested in the same manner as the Level 1 fire systems. The following was noted during the testing:

1. Detection zones do not appear to have been updated to reflect the changing fire compartments.

2. SEF-West operates on a fire event in the West Ward fire compartment.

3. SEF-East operates on a fire event in the East Ward fire compartment.

4. Fire and smoke doors all close on fire alarm in any zone.

The smoke control on these levels operates as it is designed. Again, commissioning has failed to pick up the inconsistent zoning of the smoke detection system. Additionally, the zoning for the smoke exhaust is on fire compartments, not smoke compartments, meaning that two smoke compartments are being exhausted at once, raising the possibility of smoke spread from the smoke compartment of fire origin being caused by the smoke exhaust.

It should also be noted that the location of the smoke exhaust points at the west and east fire exits on Levels 2, 3 4 and 5 may cause smoke to be dragged to the exit points on these levels.

4.8.6. General Review Outcomes

The Smoke Control Report [15] highlighted the following general issues with the fire systems:

1. Regular maintenance of the smoke hazard management system, including the detection and alarm system, was not being carried out and documented correctly.

2. The Penetration Register was not being maintained.

3. Coordination between consultants and contractors was poor during refurbishments, resulting in discrepancies between the detection system zoning and the fire and smoke compartmentation.

4. Construction and subsequent maintenance of the fire and smoke walls was poor, with the walls not providing and effective Fire Resistance Level.

5. Testing and commissioning of the smoke hazard management system changes in 1996 and 2008 was not conducted correctly.

6. Maintenance of the smoke hazard management system is not being conducted, or is being incorrectly documented.

4.8.7. Smoke Hazard Review Recommendations

The report issued by Consultant A [15] makes the following recommendations to bring the smoke hazard management system up to compliance standards:

1. Engage a contractor to re-program the Fire Indicator Panel (FIP) to have the detection zone boundaries align with the Fire/Smoke Compartment boundaries where required.

2. A smoke exhaust fan (labelled SEF-Central in the fire matrix) is installed in Level 6 plant room, providing smoke exhaust to the Lift lobby area of Levels 2-5.

3. Stair pressurisation fans (labelled SPF1, SPF-2 and SPF-3 in the fire matrix) are installed on the three stairwells in the Northern face of the building.

4. A lift well pressurisation fan is installed on Level 7.

5. Install a new smoke exhaust fan in the Level 3 Plant Room to exhaust the new Fire compartment on Level 3 (Dental).

6. Consider operating fire and smoke doors on separate detectors at no more than 1.5m from each side of the door.

7. Update all alarm zone and evacuation drawings for the hospital.

8. At completion of works conduct full testing of smoke control systems within the hospital.

9. Obtain a complete set of As Installed drawings that shows in full the Mechanical Systems fitted to the hospital.

10. Obtain a complete set of As Installed drawings that shows in full the Fire and Smoke Walls in the hospital.

11. Patch holes in existing fire and smoke walls to provide an effective smoke barrier where compartment walls are indicated on the existing drawings.

12. Patch temporary wall panels to openings around the Level 2 theatre walls and ICU ward as an interim safety measure.

13. Update the register of fire and smoke doors within the hospital for maintenance purposes.

14. Enter into a Service agreement with a fire company that will provide complete servicing, testing and maintenance of the hospitals fire systems.

4.9. SUMMARY

Hospital A was initially designed and built circa 1980 and general compliance to the codes and standards of the day can be assumed. The smoke hazard management system initially installed was based on exhausting the fire affected floor and pressurising all other floors. This system was redesigned to a zone pressurisation system, with the addition of fire and smoke compartmentation to the Ward areas in 1996. The change to zone pressurisation was no implemented according the requirements of AS/NZS 1668.1 1991.

Following the major changes in 1996 several small changes to the smoke hazard management system have been undertaken. Some of these have been implemented corrected, such as the changes to the Out Patients Department in 2008, while others have not been properly documented or commissioned, such as the changes to the Operating Theatres in 2008.

While maintenance records exist on site for the smoke hazard management system, a review of this system conducted in 2011 highlighted that this maintenance was either not being conducted correctly, or was not being documented correctly.

4.10. CONCLUSIONS

The smoke hazard management system in Hospital A has gone from a compliant vertical pressurisation system, to a non-compliant zone pressurisation system. This transformation appears to be the result of a series of refurbishments and upgrades to the hospital that have generally not contained a coordinated approach to smoke hazard management.

The deficiency in the zone pressurisation system is exacerbated by a network of smoke and fire walls that were not initially built correctly, and have subsequently been poorly maintained. When we add in to the equation the fact that the building has no sprinkler protection (as is allowed with a zone pressurisation system installed) and smoke detection zoning that does not align with the fire and smoke compartmentation in the building the potential for fatalities to occur in a fire is increased.

5. CASE STUDY 2 – HOSPITAL B

5.1. INTRODUCTION

Case Study 1 looked at an existing hospital, and the problems that multiple refurbishments and poor commissioning procedures and bad maintenance practices can cause for a smoke hazard management system. This case study looks at a regional hospital currently under construction, Hospital B, and explores issues in the design process for the smoke hazard management system. Hospital B serves a major regional centre in Queensland, and is currently undergoing a major refurbishment and expansion. This expansion involves the construction of several inter-connected multi-storey buildings on site, which will upon completion replace the existing hospital, which will be decommissioned and demolished as the new services come online.

5.2. BUILDING DESCRIPTION

The main hospital building includes a number of minor buildings that are considered as a united building under the BCA DTS provisions. Buildings A, E, F, G, H, J, L and Q form a united building. Buildings B, C, D, K and M are considered separate buildings. Refer to Figure 5.1 for a Site Plan of the hospital development. For the purposes of this Case Study, the united building is of interest, specifically Buildings E, F, G, H, J, and Q.

Building E is the central building and contains administration functions, the Operating Theatres, Recovery, the Intensive Care Unit and various isolation rooms. Building E is a five storey building, with the upper two levels, i.e. Level 3 and Level 4, being plant rooms. The Operating Theatres and Recovery Wards are contained on Level 1, with a separate plant room for Operating Theatre mechanical and ventilation services on Level 2. Building E connects to Buildings F and G via 'Main Street', or Building Q, which is essentially a four level connecting corridor between Buildings A, E, F, G and H.

Buildings F and G are four storey ward buildings, with the top level of each being plant room. The two storey Building H contains the Kitchen, mortuary and Electrical Substation. Building J is a two building containing the Mental Health Facility.

Floor plans of each building, showing fire compartmentation, can be found in Appendix D.

5.3. DEEMED TO SATISFY REQUIREMENTS

This building is still under construction, and although designed to meet the requirements of the BCA 2009 [24] it will be assessed against the requirements of the BCA 2011 for the purposes of this project. The sections of the BCA 2011 relevant to smoke hazard management are identical to those in the BCA 2009, therefore this assessment is held to be valid.

As Hospital B is a required by the BCA to be of Type A construction and is classified as a Category 2 Health Care building under AS/NZs 1668.1, the DTS requirements for this hospital are identical to those of Hospital A. Refer to Section 4.3 for a description of the DTS requirements relating to this hospital.

5.4. SMOKE HAZARD MANAGEMENT AS INSTALLED

The smoke hazard management system in Hospital B is based on the following:

1. Installation of sprinklers to meet the requirements AS 2118.1 1999,

2. Pressurisation of fire stairs in the fire affected compartment to AS/NZS 1668.1 1998,

3. Shutdown of air-handling units serving the fire affected compartment, and

4. Normal operation of air-handling units to other fire compartments to create a pressure differential with the fire affected compartment.

The above outline of the smoke hazard management system is as per the latest mechanical drawings and Fire Engineering Report [25] that the author has access to. As the hospital is still under construction, there may be minor changes to the floor layouts and building fit outs, but the smoke hazard management strategy should, at this stage of construction, remain unaltered.

5.5. MECHANICAL SYSTEM DESIGN

Design of the mechanical system was driven initially by the services risers made available by the architect, and agreed to by the mechanical consultant and Queensland Health.

Building F and Building G are each provided with two risers extending from Level 0 to Level 3, one located in each fire compartment on the Ward Levels. The Plant Room on Level 3 of these buildings contains AHUs serving each level. While multiple AHUs serve each level, no AHU serves more than one level. This allows for AHUs to be provided for each fire compartment, minimising the amount of mechanical penetrations through fire and smoke walls.

Building H has a single mechanical riser serving all levels. The Plant Room on the upper level contains AHUs serving each level. No AHU serves more than one level. In this building, although AHUs serve more than one fire compartment, motorised fire dampers are limited in number.

Building J has a single mechanical riser serving all levels. As there are multiple fire compartments on Level 0 this arrangement has led to an increase in the number of motorised fire dampers fitted to this building, as multiple ducts pass through smoke and fire walls.

Building Q has two mechanical risers, with AHUs in the Level 3 Plant Room. AHUs in this building serve a single fire compartment on each level, but serve multiple levels.

Building E, the largest and most complex building on site, is served by a single mechanical riser. There are multiple fire compartments on each level of the building, with most served by multiple AHUs. As there is a single riser in this building, a lot of duct work passes through two or more fire compartments to reach the fire compartment served.

This Case Study will concentrate on the design of the smoke hazard management system for Building E, as this is the most complex building, and the most problematic to design.

5.5.1. Fire Engineering Design Requirements

Initial smoke hazard management design for the hospital was based on a partial zone pressurisation system, with the fire affected smoke compartment AHUs shutting down, stair pressurisation and relief air for the stair pressurisation activating in the fire affected smoke compartment, and the AHUs serving all other compartments operating in normal mode. This method of smoke control would require some redesign of the mechanical system to enable implementation.

The initial Fire Matrix, also known as the Cause and Effect Matrix for Smoke Control, for Building E was submitted to the design team for review, including the Fire Engineers, Mechanical Engineers, Builder, Mechanical Contractor, Building Certifier and User Group representatives. From this review it emerged that this smoke control methodology did not comply with the requirements of the FER, and therefore could not be accepted.

A copy of the FER was provided to the engineers developing the Fire Matrix. The FER was very comprehensive in most areas, but contained only a single sentence relating the smoke hazard management system. The smoke control strategy documented in the FER called for a full system shutdown upon fire alarm. The Fire Matrix for Building E was revised to reflect the requirements of the FER, and the revised copy was issued to the design team. A sample of the Fire Matrix developed for Level 1 of building E is contained in Appendix E.

5.5.2. User Group Design Requirements

It was at this stage the design team was made aware of User Group expectations in relation to the smoke hazard management system. The User Group made their displeasure at a full shut down of air-handling plant within the hospital plain. The User Group then, upon having the choices available for smoke hazard management explained, determined that the system that would best suit their needs was one based on the fire affected compartment shutting down, with the air-handling equipment in all other compartments operating in normal mode. This was to be based on fire compartmentation to minimise mechanical system redesign required.

The Fire Matrix was revised and submitted for approval, at which point it became apparent that the chosen smoke control strategy could not be successfully implemented in all buildings due to the design of the mechanical system, which had been limited by the riser space afforded by the architectural design.

The Fire Matrix was again revised and submitted for approval. Upon approval the mechanical contractor was able to start fabricating duct and ordering dampers required to implement the smoke control methodology. Although there were several more iterations of the Fire Matrix for Building E, these were minor in nature, and generally changed the function of individual dampers or AHUs in fire mode.

5.5.3. Design Team Communication

Throughout the Fire Matrix development process it became apparent that the smoke hazard management strategy was not discussed up front by the User Group, the Mechanical Engineer and the Fire Engineer. This led to the design intent for the smoke hazard management strategy not being communicated to the architect, and so limited risers provided. This in turn limited the implementation of the smoke hazard management strategy, which had to be revised in some parts of the hospital to allow for what could physically be achieved.

5.6. SUMMARY

The design process for the smoke hazard management system was flawed, in that:

1. Consultation between the User Group, the Mechanical Engineer and the Fire Engineer relating to the smoke hazard management system did not occur until late in the design process.

2. Limited mechanical risers made available by the Architect drove the mechanical design down a path that did not allow for the preferred method of smoke hazard management to be implemented.

3. The Fire Engineer was not involved in the consultation process to achieve the final smoke hazard management design.

4. The User Group either had a poor understanding of smoke control options or incorrectly interpreted the design put forward by the Fire Engineer in his/her FER.

These factors have led the design and installation of a smoke hazard management system that, while compliant with the codes, is more complex than such a system needs to be. The added complexity has added cost, and increased the number of components, and so the likelihood of a partial failure of the system is also increased.

5.7. CONCLUSIONS

From this brief analysis it can be seen that it is important to have an agreement on a smoke control methodology as early in the design phase as possible. This allows for the intent to be communicated to all parties, allowing for the required provisions for riser space and location to be made. It also ensures that the mechanical design reflects the intent of the smoke control methodology detailed by the Fire Engineer and agreed by the design team.

6. CONSTRUCTION AND MAINTENANCE ISSUES

6.1. INTRODUCTION

From the Case Studies undertaken for this project, and from inspections and design work undertaken by the author on other hospitals in Queensland, it is apparent that there are construction and maintenance issues relating to smoke hazard management that need to be considered when designing a smoke hazard system for a hospital. This section will briefly discuss some of these issues.

6.2. FIRE AND SMOKE WALL CONSTRUCTION

Fire and smoke walls are a key component of a smoke control system in stopping the spread of fire and smoke. They become especially important in buildings where sprinklers are not fitted. Unfortunately, fire and smoke walls are often poorly constructed and are rarely well maintained.

Poor construction of smoke and fire walls sets back a smoke control strategy before the building is occupied. Although fire and smoke wall construction has improved greatly in the last decade, it can be hit and miss with builders as to how well they are constructed in a new building.

While poor construction is not ideal in a fire or smoke wall, the effects of this can be heavily outweighed by the effects of poor maintenance on the integrity of the walls, and by extension the smoke control system. Good maintenance starts with a Penetration Register that is continually updated, and regular inspections of fire and smoke walls, especially following refurbishments or extensions.

The elements of a good maintenance regime for fire and smoke walls are:

- Controlled access to ceiling voids for contractors.
- Clearly identified fire and smoke walls, both above and below ceiling.
- A Penetration Register that is kept up to date.
- Regular inspections of fire and smoke walls by a qualified tradesman.
- A sound understanding of the requirements for fire and smoke walls by hospital engineering staff.

Properly installed and well maintained fire and smoke walls will benefit a smoke control strategy greatly.

6.3. MECHANICAL SYSTEMS

Mechanical systems play a large part in a smoke control strategy, especially in a zone pressurisation system. The smoke control strategy to be employed should be agreed and communicated as early as possible in a project, allowing the mechanical design to be developed to meet the smoke control requirements.

The provision of mechanical risers to each fire compartment will greatly assist in keeping the mechanical design as simple as possible, reducing the requirement for components such as motorised dampers to enable the smoke control strategy. This in turn will keep down costs and enhance the reliability of the mechanical system.

6.4. COMMISSIONING AND MAINTENANCE

The commissioning of a smoke hazard management system is a long and complex process in a large hospital, and should not be shortcut in any way. The aim of commissioning is to ensure that the system as installed meets the functionality required of the fire Engineering and the relevant codes and standards.

At the completion of commissioning the Consulting Engineers, Building Certifier and Building Owner should be confident that the system is installed correctly and meets the performance requirements of the appropriate codes and standards. To enable this, the Commissioning process itself needs to be rigorously designed and adhered to.

Ongoing maintenance is required to ensure the system performance is maintained. Such maintenance should be conducted in accordance with AS 1851, and performed by an appropriately qualified contractor. All maintenance should be recorded in approved log books that are retained on site to provide a detailed maintenance history.

7. CONCLUSIONS

Case studies on two (2) hospitals have been undertaken to review the requirements for smoke control in health care buildings and highlight the difficulties associated with achieving functional and efficient smoke control in hospitals.

Hospital A, an existing major metropolitan hospital built circa 1980, was investigated. The findings from this case study were:

- The smoke hazard management system in Hospital A has gone from a compliant vertical pressurisation system, to a non-compliant zone pressurisation system. This transformation appears to be the result of a series of refurbishments and upgrades to the hospital that have generally not contained a coordinated approach to smoke hazard management.
- The deficiency in the zone pressurisation system is exacerbated by a network of smoke and fire walls that were not initially built correctly, and have subsequently been poorly maintained. When we add in to the equation the fact that the building has no sprinkler protection (as is allowed with a zone pressurisation system installed) and smoke detection zoning that does not align with the fire and smoke compartmentation in the building the potential for fatalities to occur in a fire is increased.

Hospital B, a major regional hospital still under construction, was also studied. The findings from this case study were:

- It is important to have an agreement on a smoke control methodology as early in the design phase as possible. This allows for the intent to be communicated to all parties, allowing for the required provisions for riser space and location to be made. It also ensures that the mechanical design reflects the intent of the smoke control methodology detailed by the Fire Engineer and agreed by the design team.

8. RECOMMENDATIONS

Based on the case studies undertaken and the results obtained, the following recommendations are made for future hospital projects:

- Any refurbishment, renovations or extensions to the hospital should reference the Fire Matrix and conform to the existing smoke control strategies, or if a new smoke control strategy is to be adopted update the Fire Matrix to suit.
- In large hospitals, individual mechanical risers should serve each fire compartment. This serves to enable smoke control with a simplified mechanical system, limiting the number of dampers required.
- Penetration Registers to be prepared during construction. Ideally the Penetration Register would be presented to the hospital engineering staff in electronic form to enable it to be updated as required.
- During design, the smoke hazard management methodology to be implemented should be agreed as early as possible and communicated clearly to all parties to enable appropriate design.
- A comprehensive commissioning plan should be developed and utilised during the commissioning of the smoke hazard management system. This commissioning plan should address compliance with all performance requirements of the applicable codes and standards.

8.1. FURTHER RESEARCH

To complement and further the work undertaken here, a comparison of the current 'Deemed to Satisfy' (DTS) requirements of the National Construction Code (NCC), Class 2 to 9 Buildings with the national codes of other countries should be undertaken, with the following aims:

- Determine from selected hospital management teams their understanding of smoke hazard management requirements and interaction with operational needs for a working hospital. This would cover processes, use and function.
- Propose changes to the BCA 2011 that will meet the needs of the health providers with regard to the performance outcomes of design for smoke hazard management.

- Propose ‘best practice’ smoke hazard management matrix for fire safety systems in hospitals.

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APPENDIX A BCA PERFORMANCE REQUIREMENTS FOR SMOKE HAZARD MANAGEMENT

CP2

a) A building must have elements, which will, to the degree necessary, avoid the spread of fire-

i) to exits; and

ii) to sole-occupancy units and public corridors; and

iii) between buildings; and

iv) in a building.

b) Avoidance of the spread of fire referred to in (a) must be appropriate to-

i) the function or use of the building; and

ii) the fire load; and

iii) the potential fire intensity; and

iv) the fire hazard; and

v) the number of storeys in the building; and

vi) its proximity to other property; and

vii) any active fire safety systems installed in the building; and

viii) the size of any fire compartment; and fire brigade intervention, and other elements they support, and the evacuation time.

CP3 A building must be protected from the spread of fire and smoke to allow sufficient time for the orderly evacuation of the building in an emergency.

EP1.4 An Automatic fire suppression system must be installed to the degree necessary to control the development and spread of fire appropriate to –

a) the size of the fire compartment; and

b) the function or use of the building; and

c) the fire hazard; and

d) the height of the building.

EP2.1

In a building providing sleeping accommodation, occupants must be provided with automatic warning on the detection of smoke so they may evacuate in the event of a fire to a safe place.

EP2.2

a) In the event of a fire in a building the conditions in any evacuation route must be maintained for the period of time occupants take to evacuate the part of the building so that –

i) the temperature will not endanger human life; and

ii) the level of visibility will enable the evacuation route to be determined; and

iii) the level of toxicity will not endanger human life.

b) The period of time occupants take to evacuate referred to in (a) must be appropriate to –

i) the number, mobility and other characteristics of the occupants; and

ii) the function or use of the building; and

iii) the travel distance and other characteristics of the building; and

iv) the fire load; and

v) the potential fire intensity; and

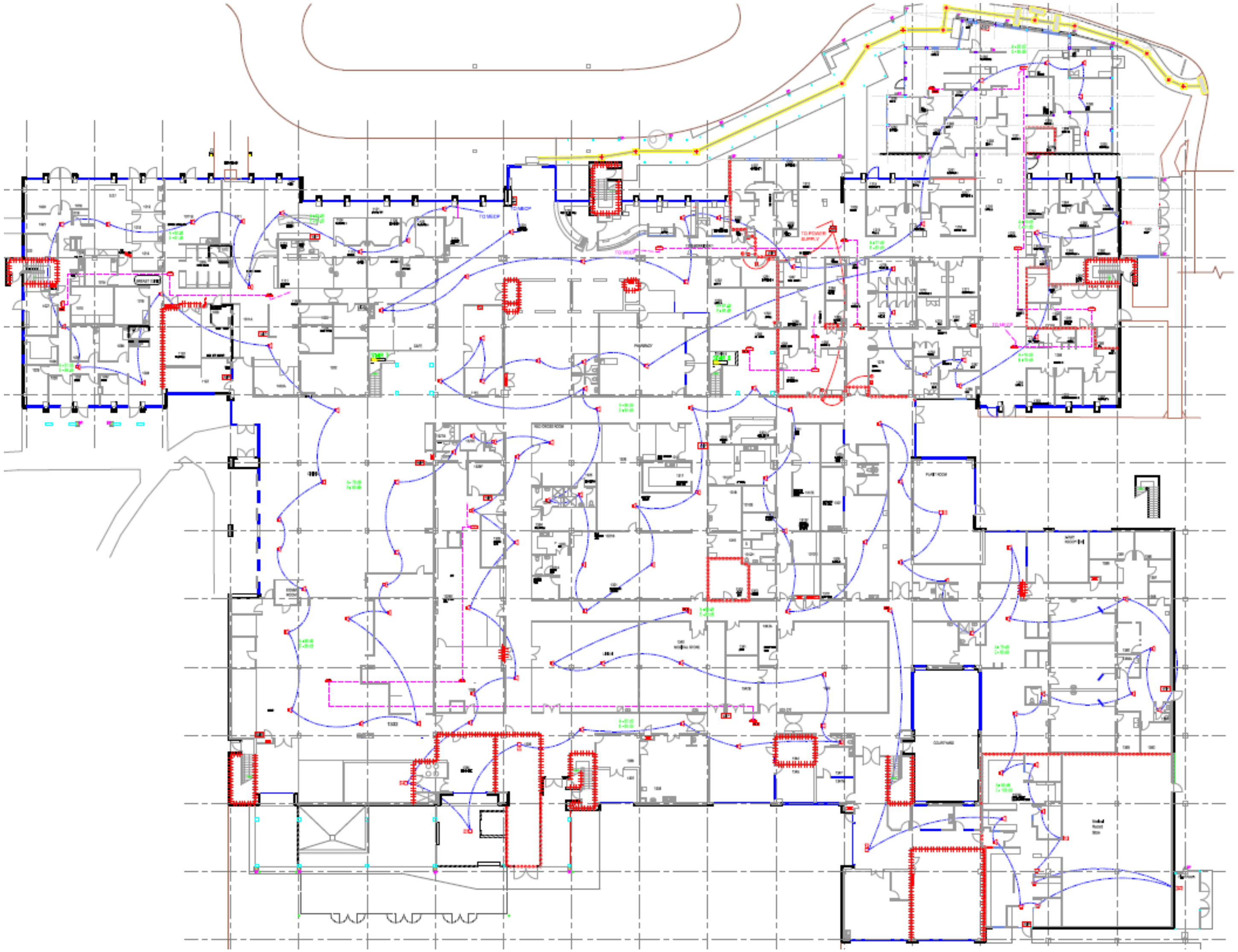
vi) the fire hazard; and

vii) any active fire safety systems installed in the building; and

viii) fire brigade intervention.

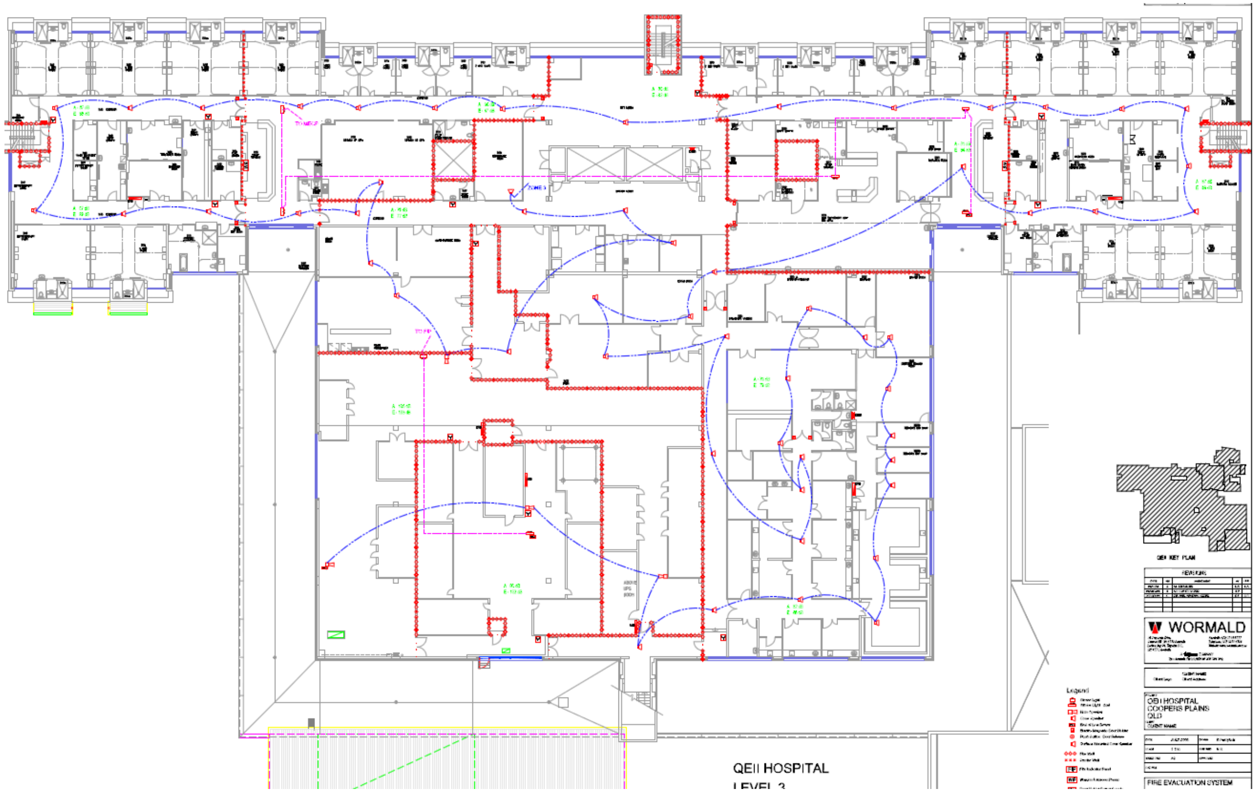
APPENDIX B HOSPITAL A FLOOR PLANS

Level 1

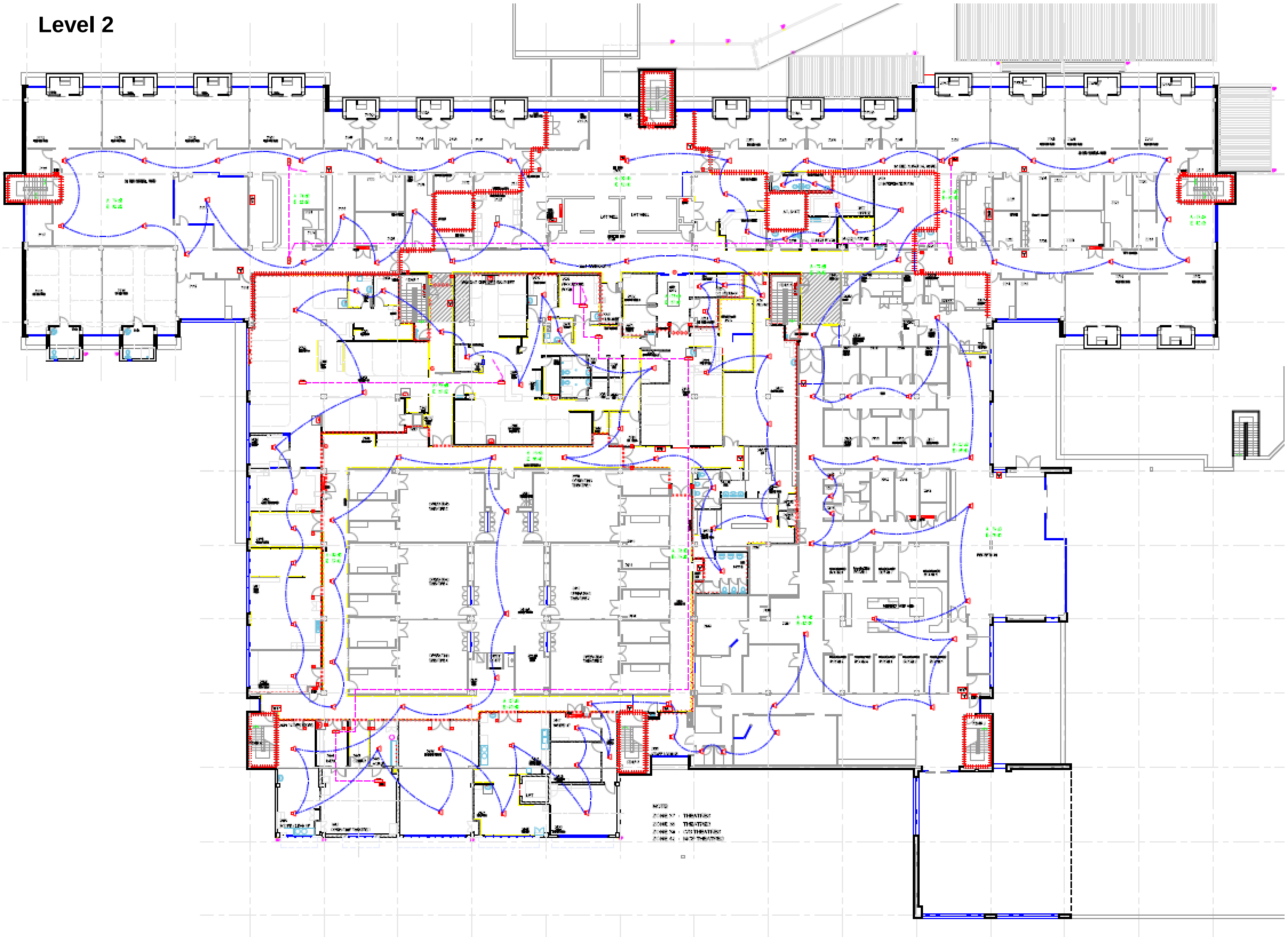


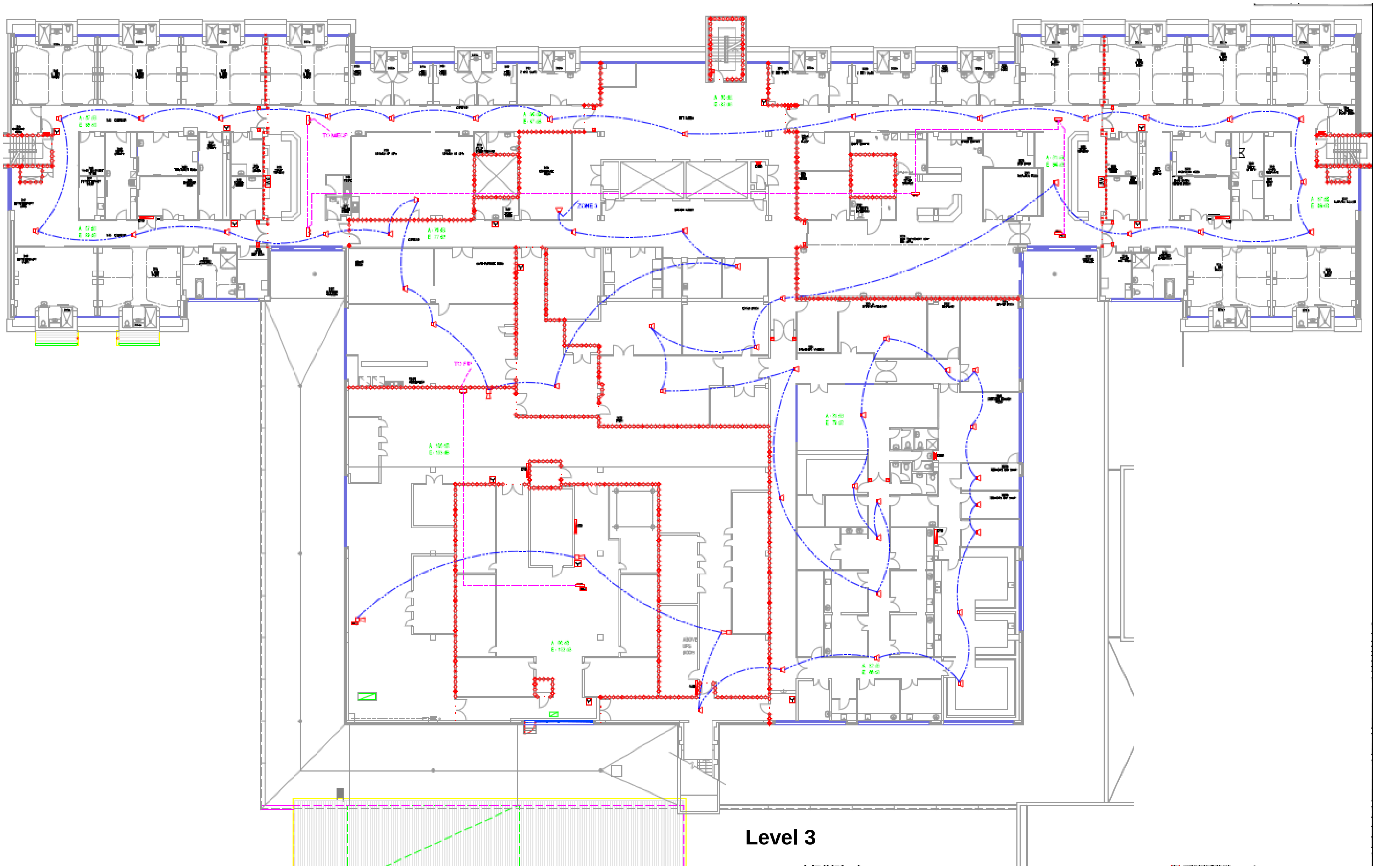
Legend

- Strobe Light
- Strobe Light - dual
- Horn Speaker
- Cone Speaker
- End of Line Device
- Electro-Magnetic Door Holder
- Push Button Door Release
- Surface Mounted Cone Speaker
- Fire Wall
- Smoke Wall
- FIP Fire Indicator Panel
- WIP Warden Intercom Phone
- PSU Door Holder Power Supply
- XX dB Decibel Reading
- PC Paging Console

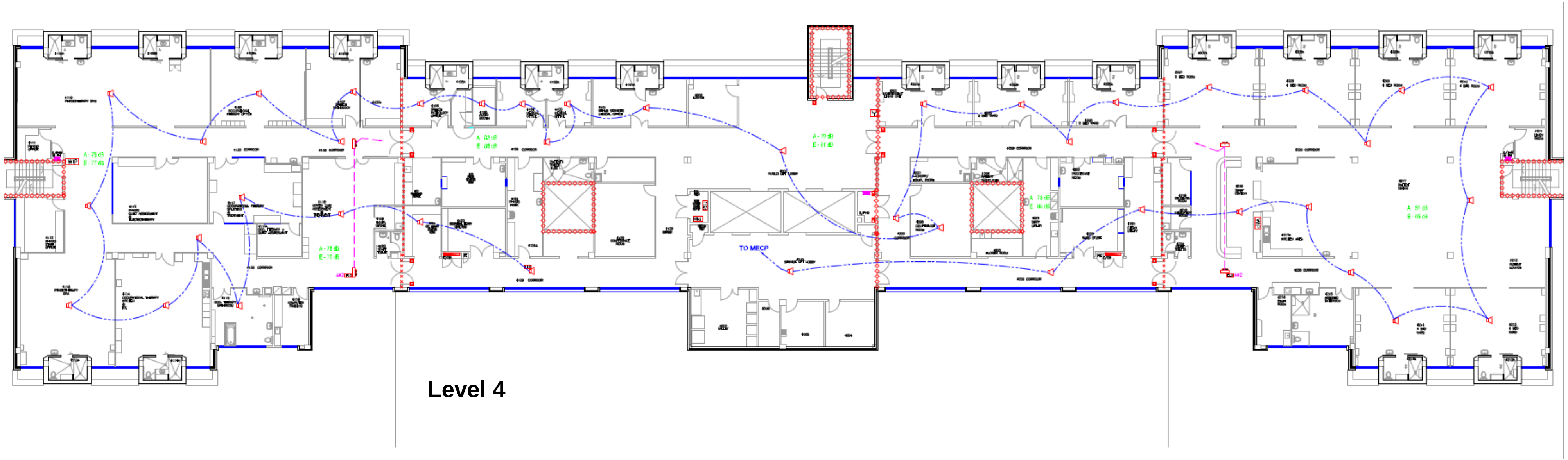

QEII HOSPITAL
Legend
REVISIONS
WORMALD
QEII HOSPITAL
COOPERS PLAINS
QLD
FIRE EVACUATION SYSTEM

Level 2

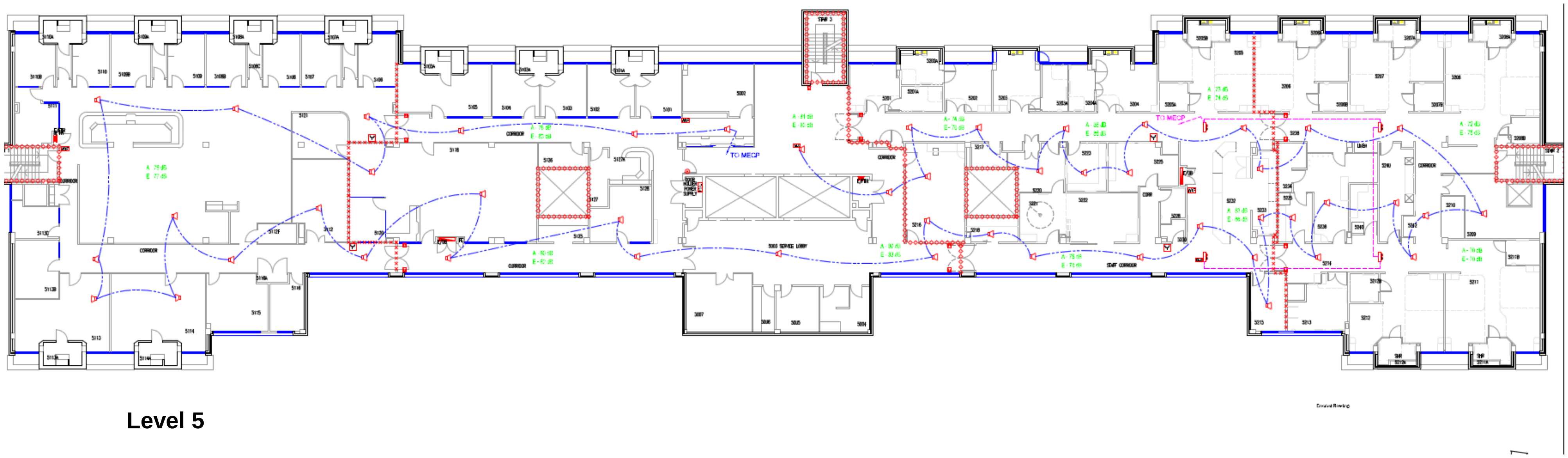




Level 3



Level 4



Level 5

APPENDIX C BRANZFIRE SUMMARY FILES HOSPITAL A

Scenario 1

```
Wednesday, March 06,2013,11:01 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 1\Level 4
OC 01.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                100.00
         Room Width (m) =                                 20.00
         Maximum Room Height (m) =                        3.50
         Minimum Room Height (m) =                        3.50
         Floor Elevation (m) =                            12.000
         Room  1  has a flat ceiling.

Zone models may not provide realistic results for large compartments where momentum
effects and large heat losses remote from the fire could cause non-uniformity in the
upper/lower layer properties. Please interpret your results with extra care.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                           810.0
         Wall Conductivity (W/m.K) =                      0.160
         Wall Emissivity =                                0.88
         Wall Thickness (mm) =                            100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                        2300.0
         Ceiling Conductivity (W/m.K) =                   1.200
         Ceiling Emissivity =                             0.50
         Ceiling Thickness (mm) =                         100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                          2300.0
         Floor Conductivity (W/m.K) =                     1.200
         Floor Emissivity =                               0.50
         Floor Thickness = (mm)                           100.0

====================================================================
Wall Vents
====================================================================
From room  1  to outside, Vent No 1
                   Vent Width (m) =                       1.200
                   Vent Height (m) =                      1.000
                   Vent Sill Height (m) =                 1.000
                   Vent Soffit Height (m) =               2.000
                   Opening Time (sec) =                   0
                   Closing Time (sec) =                   0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                       1.200
                   Vent Height (m) =                      1.000
                   Vent Sill Height (m) =                 1.000
                   Vent Soffit Height (m) =               2.000
                   Opening Time (sec) =                   0
                   Closing Time (sec) =                   0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                       24.0
```

```
Exterior Temp (C) =                                         35.0
Relative Humidity (%) =                                     50

====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =              2.00
Occupant Activity Level =                                   Light
Visibility calculations assume:                             reflective signs
FED Start Time (sec)                                        0
FED End Time (sec)                                          1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)              0.097
         Detector Characteristic Length Number (m)          15.0
         Detector Sensitivity (%/ft)                        6.6
         Radial Distance from Plume (m)                     7.100
         Distance below Ceiling (m)                         0.025
         Detector response is based on OD inside the detector chamber.
====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                                3.000
         Start Time (sec) =                                 43
         Maximum Cross-Fan Pressure Limit (Pa) =            50
         Number of Fans =                                   2
         Extract Rate per fan (m3/s) =                      6.00

====================================================================
Description of the Fire
====================================================================
Radiant Loss Fraction =                                     0.30
CO Yield pre-flashover(g/g) =                               0.040
Soot Alpha Coefficient =                                    2.80
Smoke Epsilon Coefficient =                                 1.30
Smoke Emission Coefficient (1/m) =                          1.20
Characteristic Mass Loss per Unit Area (kg/s.m2) =          0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

              Located in Room                               1
              Energy Yield (kJ/g) =                         19.0
              CO2 Yield (kg/kg fuel) =                      1.920
              Soot Yield (kg/kg fuel) =                     0.227
              HCN Yield (kg/kg fuel) =                      0.000
              Fire Height (m) =                             0.000
              Fire Location =                               Centre

              Time (sec)                Heat Release (kW)
               0                        0
               11                       6
               22                       22
               33                       50
               44                       89
               54                       139
               65                       200
               76                       272
               87                       356
               98                       450
               109                      556
               120                      672
               131                      800
               141                      939
               152                      1089
               163                      1250
               174                      1422
               185                      1606
```

```
              196                     1800
              207                     2006
              218                     2222
              229                     2450
              239                     2689
              250                     2939
              261                     3200
              272                     3472
              283                     3756
              294                     4050
              305                     4356
              316                     4672
              326.5                   5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                      Room 1    Outside

         Layer (m)                    3.500
         Upper Temp (C)               24.0
         Lower Temp (C)               24.0
         HRR (kW)                     0.0

2 min    00 sec
         (120 sec)                    Room 1    Outside

         Layer (m)                    3.273
         Upper Temp (C)               37.3
         Lower Temp (C)               24.5
         HRR (kW)                     672.2

4 min    00 sec
         (240 sec)                    Room 1    Outside

         Layer (m)                    2.805
         Upper Temp (C)               62.8
         Lower Temp (C)               26.9
         HRR (kW)                     2711.6

6 min    00 sec
         (360 sec)                    Room 1    Outside

         Layer (m)                    2.208
         Upper Temp (C)               95.2
         Lower Temp (C)               30.9
         HRR (kW)                     5000.0

8 min    00 sec
         (480 sec)                    Room 1    Outside

         Layer (m)                    1.992
         Upper Temp (C)               102.0
         Lower Temp (C)               35.6
         HRR (kW)                     5000.0

10 min   00 sec
         (600 sec)                    Room 1    Outside

         Layer (m)                    1.876
         Upper Temp (C)               104.8
         Lower Temp (C)               39.0
         HRR (kW)                     5000.0

12 min   00 sec
         (720 sec)                    Room 1    Outside
```

```
        Layer (m)                      1.779
        Upper Temp (C)                 107.0
        Lower Temp (C)                 41.4
        HRR (kW)                       5000.0

14 min  00 sec
        (840 sec)                      Room 1    Outside

        Layer (m)                      1.697
        Upper Temp (C)                 108.8
        Lower Temp (C)                 43.0
        HRR (kW)                       5000.0

16 min  00 sec
        (960 sec)                      Room 1    Outside

        Layer (m)                      1.631
        Upper Temp (C)                 110.3
        Lower Temp (C)                 44.2
        HRR (kW)                       5000.0

18 min  00 sec
        (1080 sec)                     Room 1    Outside

        Layer (m)                      1.576
        Upper Temp (C)                 111.7
        Lower Temp (C)                 45.2
        HRR (kW)                       5000.0

20 min  00 sec
        (1200 sec)                     Room 1    Outside

        Layer (m)                      1.532
        Upper Temp (C)                 112.9
        Lower Temp (C)                 46.0
        HRR (kW)                       5000.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 43 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 855.0 Seconds.
FED thermal (incap) exceeded 0.3 at 594.0 Seconds.
An Upper Layer Temperature of 200 deg C Not Reached.
Visibility at 2m above floor reduced to 10 m at 473.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 473.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 32.6 seconds.
====================================================================
```

Scenario 2

```
Wednesday, March 06,2013,11:03 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 2\Level 4
OC 02.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                  100.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  1  has a flat ceiling.

Zone models may not provide realistic results for large compartments where momentum
effects and large heat losses remote from the fire could cause non-uniformity in the
upper/lower layer properties. Please interpret your results with extra care.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                             810.0
         Wall Conductivity (W/m.K) =                        0.160
         Wall Emissivity =                                  0.88
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

====================================================================
Wall Vents
====================================================================
From room  1  to outside, Vent No 1
                   Vent Width (m) =                         1.200
                   Vent Height (m) =                        1.000
                   Vent Sill Height (m) =                   1.000
                   Vent Soffit Height (m) =                 2.000
                   Opening Time (sec) =                     0
                   Closing Time (sec) =                     0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                         1.200
                   Vent Height (m) =                        1.000
                   Vent Sill Height (m) =                   1.000
                   Vent Soffit Height (m) =                 2.000
                   Opening Time (sec) =                     0
                   Closing Time (sec) =                     0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                         24.0
Exterior Temp (C) =                                         35.0
Relative Humidity (%) =                                     50
```

```
======================================================================
Tenability Parameters
======================================================================
Monitoring Height for Visibility and FED (m) =            2.00
Occupant Activity Level =                                 Light
Visibility calculations assume:                           reflective signs
FED Start Time (sec)                                      0
FED End Time (sec)                                        1200

======================================================================
Sprinkler / Detector Parameters
======================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)            0.097
         Detector Characteristic Length Number (m)        15.0
         Detector Sensitivity (%/ft)                      6.6
         Radial Distance from Plume (m)                   7.100
         Distance below Ceiling (m)                       0.025
         Detector response is based on OD inside the detector chamber.
======================================================================
Mechanical Ventilation (to/from outside)
======================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                              3.000
         Start Time (sec) =                               43
         Maximum Cross-Fan Pressure Limit (Pa) =          50
         Number of Fans =                                 2
         Extract Rate per fan (m3/s) =                    10.00

======================================================================
Description of the Fire
======================================================================
Radiant Loss Fraction =                                   0.30
CO Yield pre-flashover(g/g) =                             0.040
Soot Alpha Coefficient =                                  2.80
Smoke Epsilon Coefficient =                               1.30
Smoke Emission Coefficient (1/m) =                        1.20
Characteristic Mass Loss per Unit Area (kg/s.m2) =        0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

              Located in Room                             1
              Energy Yield (kJ/g) =                       19.0
              CO2 Yield (kg/kg fuel) =                    1.920
              Soot Yield (kg/kg fuel) =                   0.227
              HCN Yield (kg/kg fuel) =                    0.000
              Fire Height (m) =                           0.000
              Fire Location =                             Centre

              Time (sec)               Heat Release (kW)
               0                       0
               11                      6
               22                      22
               33                      50
               44                      89
               54                      139
               65                      200
               76                      272
               87                      356
               98                      450
               109                     556
               120                     672
               131                     800
               141                     939
               152                     1089
               163                     1250
               174                     1422
               185                     1606
               196                     1800
               207                     2006
               218                     2222
```

```
              229                     2450
              239                     2689
              250                     2939
              261                     3200
              272                     3472
              283                     3756
              294                     4050
              305                     4356
              316                     4672
              326.5                   5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                      Room 1    Outside

         Layer (m)                    3.500
         Upper Temp (C)               24.0
         Lower Temp (C)               24.0
         HRR (kW)                     0.0

2 min    00 sec
         (120 sec)                    Room 1    Outside

         Layer (m)                    3.273
         Upper Temp (C)               37.3
         Lower Temp (C)               24.6
         HRR (kW)                     672.2

4 min    00 sec
         (240 sec)                    Room 1    Outside

         Layer (m)                    2.805
         Upper Temp (C)               62.9
         Lower Temp (C)               27.5
         HRR (kW)                     2711.6

6 min    00 sec
         (360 sec)                    Room 1    Outside

         Layer (m)                    2.206
         Upper Temp (C)               95.4
         Lower Temp (C)               31.7
         HRR (kW)                     5000.0

8 min    00 sec
         (480 sec)                    Room 1    Outside

         Layer (m)                    1.993
         Upper Temp (C)               102.1
         Lower Temp (C)               36.1
         HRR (kW)                     5000.0

10 min   00 sec
         (600 sec)                    Room 1    Outside

         Layer (m)                    1.939
         Upper Temp (C)               104.8
         Lower Temp (C)               39.0
         HRR (kW)                     5000.0

12 min   00 sec
         (720 sec)                    Room 1    Outside

         Layer (m)                    1.924
         Upper Temp (C)               106.7
```

```
        Lower Temp (C)                40.8
        HRR (kW)                      5000.0

14 min  00 sec
        (840 sec)                     Room 1    Outside

        Layer (m)                     1.919
        Upper Temp (C)                108.2
        Lower Temp (C)                42.0
        HRR (kW)                      5000.0

16 min  00 sec
        (960 sec)                     Room 1    Outside

        Layer (m)                     1.917
        Upper Temp (C)                109.4
        Lower Temp (C)                42.9
        HRR (kW)                      5000.0

18 min  00 sec
        (1080 sec)                    Room 1    Outside

        Layer (m)                     1.916
        Upper Temp (C)                110.5
        Lower Temp (C)                43.7
        HRR (kW)                      5000.0

20 min  00 sec
        (1200 sec)                    Room 1    Outside

        Layer (m)                     1.916
        Upper Temp (C)                111.5
        Lower Temp (C)                44.3
        HRR (kW)                      5000.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 43 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 859.0 Seconds.
FED thermal (incap) exceeded 0.3 at 594.0 Seconds.
An Upper Layer Temperature of 200 deg C Not Reached.
Visibility at 2m above floor reduced to 10 m at 473.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 473.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 32.5 seconds.
====================================================================
```

Scenario 3

```
Wednesday, March 06,2013,11:07 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 3\Level 4
OC 03.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                 100.00
         Room Width (m) =                                  20.00
         Maximum Room Height (m) =                         3.50
         Minimum Room Height (m) =                         3.50
         Floor Elevation (m) =                             12.000
         Room  1  has a flat ceiling.

Zone models may not provide realistic results for large compartments where momentum
effects and large heat losses remote from the fire could cause non-uniformity in the
upper/lower layer properties. Please interpret your results with extra care.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                            810.0
         Wall Conductivity (W/m.K) =                       0.160
         Wall Emissivity =                                 0.88
         Wall Thickness (mm) =                             100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                         2300.0
         Ceiling Conductivity (W/m.K) =                    1.200
         Ceiling Emissivity =                              0.50
         Ceiling Thickness (mm) =                          100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                           2300.0
         Floor Conductivity (W/m.K) =                      1.200
         Floor Emissivity =                                0.50
         Floor Thickness = (mm)                            100.0

====================================================================
Wall Vents
====================================================================
From room  1  to outside, Vent No 1
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                        24.0
Exterior Temp (C) =                                        35.0
Relative Humidity (%) =                                    50
```

```
====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =            2.00
Occupant Activity Level =                                 Light
Visibility calculations assume:                           reflective signs
FED Start Time (sec)                                      0
FED End Time (sec)                                        1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)            0.097
         Detector Characteristic Length Number (m)        15.0
         Detector Sensitivity (%/ft)                      6.6
         Radial Distance from Plume (m)                   7.100
         Distance below Ceiling (m)                       0.025
         Detector response is based on OD inside the detector chamber.
====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                              3.000
         Start Time (sec) =                               86
         Maximum Cross-Fan Pressure Limit (Pa) =          50
         Number of Fans =                                 2
         Extract Rate per fan (m3/s) =                    6.00

====================================================================
Description of the Fire
====================================================================
Radiant Loss Fraction =                                   0.30
CO Yield pre-flashover(g/g) =                             0.040
Soot Alpha Coefficient =                                  2.50
Smoke Epsilon Coefficient =                               1.20
Smoke Emission Coefficient (1/m) =                        0.80
Characteristic Mass Loss per Unit Area (kg/s.m2) =        0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

              Located in Room                             1
              Energy Yield (kJ/g) =                       12.4
              CO2 Yield (kg/kg fuel) =                    1.190
              Soot Yield (kg/kg fuel) =                   0.015
              HCN Yield (kg/kg fuel) =                    0.000
              Fire Height (m) =                           0.000
              Fire Location =                             Centre

              Time (sec)               Heat Release (kW)
               0                       0
               11                      6
               22                      22
               33                      50
               44                      89
               54                      139
               65                      200
               76                      272
               87                      356
               98                      450
               109                     556
               120                     672
               131                     800
               141                     939
               152                     1089
               163                     1250
               174                     1422
               185                     1606
               196                     1800
               207                     2006
               218                     2222
```

```
               229                     2450
               239                     2689
               250                     2939
               261                     3200
               272                     3472
               283                     3756
               294                     4050
               305                     4356
               316                     4672
               326.5                   5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                       Room 1    Outside

         Layer (m)                     3.500
         Upper Temp (C)                24.0
         Lower Temp (C)                24.0
         HRR (kW)                      0.0

2 min    00 sec
         (120 sec)                     Room 1    Outside

         Layer (m)                     3.269
         Upper Temp (C)                41.7
         Lower Temp (C)                24.2
         HRR (kW)                      672.2

4 min    00 sec
         (240 sec)                     Room 1    Outside

         Layer (m)                     2.796
         Upper Temp (C)                66.2
         Lower Temp (C)                26.3
         HRR (kW)                      2711.6

6 min    00 sec
         (360 sec)                     Room 1    Outside

         Layer (m)                     2.199
         Upper Temp (C)                98.8
         Lower Temp (C)                30.7
         HRR (kW)                      5000.0

8 min    00 sec
         (480 sec)                     Room 1    Outside

         Layer (m)                     1.984
         Upper Temp (C)                105.3
         Lower Temp (C)                35.8
         HRR (kW)                      5000.0

10 min   00 sec
         (600 sec)                     Room 1    Outside

         Layer (m)                     1.856
         Upper Temp (C)                108.4
         Lower Temp (C)                39.5
         HRR (kW)                      5000.0

12 min   00 sec
         (720 sec)                     Room 1    Outside

         Layer (m)                     1.748
         Upper Temp (C)                110.7
```

```
        Lower Temp (C)                42.1
        HRR (kW)                      5000.0

14 min  00 sec
        (840 sec)                     Room 1    Outside

        Layer (m)                     1.659
        Upper Temp (C)                112.6
        Lower Temp (C)                43.9
        HRR (kW)                      5000.0

16 min  00 sec
        (960 sec)                     Room 1    Outside

        Layer (m)                     1.587
        Upper Temp (C)                114.2
        Lower Temp (C)                45.2
        HRR (kW)                      5000.0

18 min  00 sec
        (1080 sec)                    Room 1    Outside

        Layer (m)                     1.528
        Upper Temp (C)                115.6
        Lower Temp (C)                46.2
        HRR (kW)                      5000.0

20 min  00 sec
        (1200 sec)                    Room 1    Outside

        Layer (m)                     1.481
        Upper Temp (C)                116.9
        Lower Temp (C)                47.1
        HRR (kW)                      5000.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 86 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 738.0 Seconds.
FED thermal (incap) exceeded 0.3 at 577.0 Seconds.
An Upper Layer Temperature of 200 deg C Not Reached.
Visibility at 2m above floor reduced to 10 m at 467.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 467.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 32.4 seconds.
====================================================================
```

Scenario 4

```
Wednesday, March 06,2013,11:24 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 4\Level 4
OC 04.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                  100.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  1  has a flat ceiling.

Zone models may not provide realistic results for large compartments where momentum
effects and large heat losses remote from the fire could cause non-uniformity in the
upper/lower layer properties. Please interpret your results with extra care.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                             810.0
         Wall Conductivity (W/m.K) =                        0.160
         Wall Emissivity =                                  0.88
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

====================================================================
Wall Vents
====================================================================
From room  1  to outside, Vent No 1
                   Vent Width (m) =                         1.200
                   Vent Height (m) =                        1.000
                   Vent Sill Height (m) =                   1.000
                   Vent Soffit Height (m) =                 2.000
                   Opening Time (sec) =                     0
                   Closing Time (sec) =                     0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                         1.200
                   Vent Height (m) =                        1.000
                   Vent Sill Height (m) =                   1.000
                   Vent Soffit Height (m) =                 2.000
                   Opening Time (sec) =                     0
                   Closing Time (sec) =                     0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                         24.0
Exterior Temp (C) =                                         35.0
Relative Humidity (%) =                                     50
```

```
====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =          2.00
Occupant Activity Level =                               Light
Visibility calculations assume:                         reflective signs
FED Start Time (sec)                                    0
FED End Time (sec)                                      1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)          0.097
         Detector Characteristic Length Number (m)      15.0
         Detector Sensitivity (%/ft)                    6.6
         Radial Distance from Plume (m)                 7.100
         Distance below Ceiling (m)                     0.025
         Detector response is based on OD inside the detector chamber.
====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                            3.000
         Start Time (sec) =                             86
         Maximum Cross-Fan Pressure Limit (Pa) =        50
         Number of Fans =                               2
         Extract Rate per fan (m3/s) =                  10.00

====================================================================
Description of the Fire
====================================================================
Radiant Loss Fraction =                                 0.30
CO Yield pre-flashover(g/g) =                           0.040
Soot Alpha Coefficient =                                2.50
Smoke Epsilon Coefficient =                             1.20
Smoke Emission Coefficient (1/m) =                      0.80
Characteristic Mass Loss per Unit Area (kg/s.m2) =      0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

              Located in Room                           1
              Energy Yield (kJ/g) =                     12.4
              CO2 Yield (kg/kg fuel) =                  1.190
              Soot Yield (kg/kg fuel) =                 0.015
              HCN Yield (kg/kg fuel) =                  0.000
              Fire Height (m) =                         0.000
              Fire Location =                           Centre

              Time (sec)               Heat Release (kW)
               0                       0
               11                      6
               22                      22
               33                      50
               44                      89
               54                      139
               65                      200
               76                      272
               87                      356
               98                      450
               109                     556
               120                     672
               131                     800
               141                     939
               152                     1089
               163                     1250
               174                     1422
               185                     1606
               196                     1800
               207                     2006
               218                     2222
```

```
          229                    2450
          239                    2689
          250                    2939
          261                    3200
          272                    3472
          283                    3756
          294                    4050
          305                    4356
          316                    4672
          326.5                  5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                      Room 1    Outside

         Layer (m)                    3.500
         Upper Temp (C)               24.0
         Lower Temp (C)               24.0
         HRR (kW)                     0.0

2 min    00 sec
         (120 sec)                    Room 1    Outside

         Layer (m)                    3.269
         Upper Temp (C)               41.7
         Lower Temp (C)               24.2
         HRR (kW)                     672.2

4 min    00 sec
         (240 sec)                    Room 1    Outside

         Layer (m)                    2.796
         Upper Temp (C)               66.3
         Lower Temp (C)               26.8
         HRR (kW)                     2711.6

6 min    00 sec
         (360 sec)                    Room 1    Outside

         Layer (m)                    2.198
         Upper Temp (C)               99.0
         Lower Temp (C)               31.3
         HRR (kW)                     5000.0

8 min    00 sec
         (480 sec)                    Room 1    Outside

         Layer (m)                    1.989
         Upper Temp (C)               105.5
         Lower Temp (C)               36.2
         HRR (kW)                     5000.0

10 min   00 sec
         (600 sec)                    Room 1    Outside

         Layer (m)                    1.939
         Upper Temp (C)               108.3
         Lower Temp (C)               39.4
         HRR (kW)                     5000.0

12 min   00 sec
         (720 sec)                    Room 1    Outside

         Layer (m)                    1.925
         Upper Temp (C)               110.3
```

```
         Lower Temp (C)                 41.4
         HRR (kW)                       5000.0

14 min   00 sec
         (840 sec)                      Room 1    Outside

         Layer (m)                      1.920
         Upper Temp (C)                 111.9
         Lower Temp (C)                 42.7
         HRR (kW)                       5000.0

16 min   00 sec
         (960 sec)                      Room 1    Outside

         Layer (m)                      1.918
         Upper Temp (C)                 113.2
         Lower Temp (C)                 43.7
         HRR (kW)                       5000.0

18 min   00 sec
         (1080 sec)                     Room 1    Outside

         Layer (m)                      1.917
         Upper Temp (C)                 114.3
         Lower Temp (C)                 44.5
         HRR (kW)                       5000.0

20 min   00 sec
         (1200 sec)                     Room 1    Outside

         Layer (m)                      1.916
         Upper Temp (C)                 115.3
         Lower Temp (C)                 45.2
         HRR (kW)                       5000.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 86 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 740.0 Seconds.
FED thermal (incap) exceeded 0.3 at 577.0 Seconds.
An Upper Layer Temperature of 200 deg C Not Reached.
Visibility at 2m above floor reduced to 10 m at 468.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 468.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 32.6 seconds.
====================================================================
```

Scenario 5

```
Thursday, March 07,2013,10:13 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 5\Level 4
OC 05.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                  25.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  1  has a flat ceiling.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                             810.0
         Wall Conductivity (W/m.K) =                        0.160
         Wall Emissivity =                                  0.88
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

Room  2  :
         Room Length (m) =                                  25.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  2  has a flat ceiling.

         Wall Surface is concrete
         Wall Density (kg/m3) =                             2300.0
         Wall Conductivity (W/m.K) =                        1.200
         Wall Emissivity =                                  0.50
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

====================================================================
Wall Vents
====================================================================
From room  1  to  2 , Vent No 1
                   Vent Width (m) =                         0.006
                   Vent Height (m) =                        2.000
                   Vent Sill Height (m) =                   0.000
```

```
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to  2 , Vent No 2
                   Vent Width (m) =                        0.006
                   Vent Height (m) =                       2.000
                   Vent Sill Height (m) =                  0.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 1
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                        24.0
Exterior Temp (C) =                                        35.0
Relative Humidity (%) =                                    50

====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =             2.00
Occupant Activity Level =                                  Light
Visibility calculations assume:                            reflective signs
FED Start Time (sec)                                       0
FED End Time (sec)                                         1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)             0.097
         Detector Characteristic Length Number (m)         15.0
         Detector Sensitivity (%/ft)                       6.6
         Radial Distance from Plume (m)                    7.100
         Distance below Ceiling (m)                        0.025
         Detector response is based on OD inside the detector chamber.

====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                               3.000
         Start Time (sec) =                                43
         Maximum Cross-Fan Pressure Limit (Pa) =           50
         Number of Fans =                                  1
         Extract Rate per fan (m3/s) =                     6.00
Mechanical Ventilation installed in Room 2
         Do not use fan curve
         Fan Elevation (m) =                               3.000
         Start Time (sec) =                                1200
         Maximum Cross-Fan Pressure Limit (Pa) =           50
```

```
        Number of Fans =                                    1
        Extract Rate per fan (m3/s) =                       6.00

====================================================================
Description of the Fire
====================================================================
Radiant Loss Fraction =                                     0.30
CO Yield pre-flashover(g/g) =                               0.040
Soot Alpha Coefficient =                                    2.50
Smoke Epsilon Coefficient =                                 1.20
Smoke Emission Coefficient (1/m) =                          0.80
Characteristic Mass Loss per Unit Area (kg/s.m2) =          0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

             Located in Room                                1
             Energy Yield (kJ/g) =                          19.0
             CO2 Yield (kg/kg fuel) =                       1.920
             Soot Yield (kg/kg fuel) =                      0.227
             HCN Yield (kg/kg fuel) =                       0.000
             Fire Height (m) =                              0.000
             Fire Location =                                Centre

             Time (sec)              Heat Release (kW)
              0                      0
              11                     6
              22                     22
              33                     50
              44                     89
              54                     139
              65                     200
              76                     272
              87                     356
              98                     450
              109                    556
              120                    672
              131                    800
              141                    939
              152                    1089
              163                    1250
              174                    1422
              185                    1606
              196                    1800
              207                    2006
              218                    2222
              229                    2450
              239                    2689
              250                    2939
              261                    3200
              272                    3472
              283                    3756
              294                    4050
              305                    4356
              316                    4672
              326.5                  5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                     Room 1    Room 2    Outside

         Layer (m)                   3.500     3.500
         Upper Temp (C)              24.0      24.0
         Lower Temp (C)              24.0      24.0
         HRR (kW)                    0.0       0.0
```

2 min 00 sec

(120 sec)	Room 1	Room 2	Outside
Layer (m)	2.729	3.500	
Upper Temp (C)	52.2	24.0	
Lower Temp (C)	25.9	24.0	
HRR (kW)	672.2	0.0	

4 min 00 sec

(240 sec)	Room 1	Room 2	Outside
Layer (m)	1.881	3.500	
Upper Temp (C)	114.8	24.0	
Lower Temp (C)	32.0	24.0	
HRR (kW)	2711.6	0.0	

6 min 00 sec

(360 sec)	Room 1	Room 2	Outside
Layer (m)	0.628	3.499	
Upper Temp (C)	189.0	24.3	
Lower Temp (C)	56.1	24.0	
HRR (kW)	5000.0	0.0	

8 min 00 sec

(480 sec)	Room 1	Room 2	Outside
Layer (m)	0.266	3.499	
Upper Temp (C)	222.3	24.0	
Lower Temp (C)	74.7	24.0	
HRR (kW)	5000.0	0.0	

10 min 00 sec

(600 sec)	Room 1	Room 2	Outside
Layer (m)	0.267	3.499	
Upper Temp (C)	232.9	24.0	
Lower Temp (C)	65.8	24.0	
HRR (kW)	5000.0	0.0	

12 min 00 sec

(720 sec)	Room 1	Room 2	Outside
Layer (m)	0.271	3.499	
Upper Temp (C)	238.5	24.0	
Lower Temp (C)	68.7	24.0	
HRR (kW)	5000.0	0.0	

14 min 00 sec

(840 sec)	Room 1	Room 2	Outside
Layer (m)	0.270	3.499	
Upper Temp (C)	242.9	24.0	
Lower Temp (C)	71.8	24.0	
HRR (kW)	5000.0	0.0	

16 min 00 sec

(960 sec)	Room 1	Room 2	Outside
Layer (m)	0.269	3.499	
Upper Temp (C)	246.7	24.0	
Lower Temp (C)	74.6	24.0	
HRR (kW)	5000.0	0.0	

18 min 00 sec

(1080 sec)	Room 1	Room 2	Outside
Layer (m)	0.267	3.499	
Upper Temp (C)	250.0	24.0	
Lower Temp (C)	77.0	24.0	
HRR (kW)	5000.0	0.0	

20 min 00 sec

```
        (1200 sec)                   Room 1    Room 2    Outside

        Layer (m)                    0.266     3.499
        Upper Temp (C)               252.8     24.0
        Lower Temp (C)               78.1      24.0
        HRR (kW)                     5000.0    0.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 43 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 492.0 Seconds.
FED thermal (incap) exceeded 0.3 at 287.0 Seconds.
Upper Layer Temperature Exceeds 200 deg C at 390.0 Seconds.
Visibility at 2m above floor reduced to 10 m at 221.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 221.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 19.7 seconds.
====================================================================
```

Scenario 6

```
Thursday, March 07,2013,11:02 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 6\Level 4
OC 06.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                  25.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  1  has a flat ceiling.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                             810.0
         Wall Conductivity (W/m.K) =                        0.160
         Wall Emissivity =                                  0.88
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

Room  2  :
         Room Length (m) =                                  25.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  2  has a flat ceiling.

         Wall Surface is concrete
         Wall Density (kg/m3) =                             2300.0
         Wall Conductivity (W/m.K) =                        1.200
         Wall Emissivity =                                  0.50
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

====================================================================
Wall Vents
====================================================================
From room  1  to  2 , Vent No 1
                   Vent Width (m) =                         0.006
                   Vent Height (m) =                        2.000
                   Vent Sill Height (m) =                   0.000
```

```
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to  2 , Vent No 2
                   Vent Width (m) =                        0.006
                   Vent Height (m) =                       2.000
                   Vent Sill Height (m) =                  0.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 1
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                        24.0
Exterior Temp (C) =                                        35.0
Relative Humidity (%) =                                    50

====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =             2.00
Occupant Activity Level =                                  Light
Visibility calculations assume:                            reflective signs
FED Start Time (sec)                                       0
FED End Time (sec)                                         1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)             0.097
         Detector Characteristic Length Number (m)         15.0
         Detector Sensitivity (%/ft)                       6.6
         Radial Distance from Plume (m)                    7.100
         Distance below Ceiling (m)                        0.025
         Detector response is based on OD inside the detector chamber.

====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                               3.000
         Start Time (sec) =                                43
         Maximum Cross-Fan Pressure Limit (Pa) =           50
         Number of Fans =                                  2
         Extract Rate per fan (m3/s) =                     10.00
Mechanical Ventilation installed in Room 2
         Do not use fan curve
         Fan Elevation (m) =                               3.000
         Start Time (sec) =                                1200
         Maximum Cross-Fan Pressure Limit (Pa) =           50
```

```
         Number of Fans =                                   1
         Extract Rate per fan (m3/s) =                      0.00

====================================================================
Description of the Fire
====================================================================
Radiant Loss Fraction =                                     0.30
CO Yield pre-flashover(g/g) =                               0.040
Soot Alpha Coefficient =                                    2.50
Smoke Epsilon Coefficient =                                 1.20
Smoke Emission Coefficient (1/m) =                          0.80
Characteristic Mass Loss per Unit Area (kg/s.m2) =          0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

              Located in Room                               1
              Energy Yield (kJ/g) =                         19.0
              CO2 Yield (kg/kg fuel) =                      1.920
              Soot Yield (kg/kg fuel) =                     0.227
              HCN Yield (kg/kg fuel) =                      0.000
              Fire Height (m) =                             0.000
              Fire Location =                               Centre

              Time (sec)              Heat Release (kW)
               0                      0
               11                     6
               22                     22
               33                     50
               44                     89
               54                     139
               65                     200
               76                     272
               87                     356
               98                     450
               109                    556
               120                    672
               131                    800
               141                    939
               152                    1089
               163                    1250
               174                    1422
               185                    1606
               196                    1800
               207                    2006
               218                    2222
               229                    2450
               239                    2689
               250                    2939
               261                    3200
               272                    3472
               283                    3756
               294                    4050
               305                    4356
               316                    4672
               326.5                  5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                      Room 1     Room 2     Outside

         Layer (m)                    3.500      3.500
         Upper Temp (C)               24.0       24.0
         Lower Temp (C)               24.0       24.0
         HRR (kW)                     0.0        0.0
```

```
2 min    00 sec
         (120 sec)                    Room 1    Room 2    Outside

         Layer (m)                    2.753     3.500
         Upper Temp (C)               52.7      24.0
         Lower Temp (C)               27.6      24.0
         HRR (kW)                     672.2     0.0

4 min    00 sec
         (240 sec)                    Room 1    Room 2    Outside

         Layer (m)                    2.192     3.500
         Upper Temp (C)               116.9     24.0
         Lower Temp (C)               34.4      24.0
         HRR (kW)                     2711.6    0.0

6 min    00 sec
         (360 sec)                    Room 1    Room 2    Outside

         Layer (m)                    1.975     3.500
         Upper Temp (C)               179.6     24.0
         Lower Temp (C)               42.1      24.0
         HRR (kW)                     5000.0    0.0

8 min    00 sec
         (480 sec)                    Room 1    Room 2    Outside

         Layer (m)                    1.976     3.500
         Upper Temp (C)               187.6     24.0
         Lower Temp (C)               47.1      24.0
         HRR (kW)                     5000.0    0.0

10 min   00 sec
         (600 sec)                    Room 1    Room 2    Outside

         Layer (m)                    1.973     3.500
         Upper Temp (C)               191.3     24.0
         Lower Temp (C)               49.4      24.0
         HRR (kW)                     5000.0    0.0

12 min   00 sec
         (720 sec)                    Room 1    Room 2    Outside

         Layer (m)                    1.971     3.500
         Upper Temp (C)               194.0     24.0
         Lower Temp (C)               50.9      24.0
         HRR (kW)                     5000.0    0.0

14 min   00 sec
         (840 sec)                    Room 1    Room 2    Outside

         Layer (m)                    1.969     3.500
         Upper Temp (C)               196.2     24.0
         Lower Temp (C)               52.1      24.0
         HRR (kW)                     5000.0    0.0

16 min   00 sec
         (960 sec)                    Room 1    Room 2    Outside

         Layer (m)                    1.968     3.500
         Upper Temp (C)               198.1     24.0
         Lower Temp (C)               53.2      24.0
         HRR (kW)                     5000.0    0.0

18 min   00 sec
         (1080 sec)                   Room 1    Room 2    Outside

         Layer (m)                    1.966     3.500
         Upper Temp (C)               199.7     24.0
         Lower Temp (C)               54.1      24.0
         HRR (kW)                     5000.0    0.0

20 min   00 sec
```

```
        (1200 sec)                      Room 1    Room 2    Outside

        Layer (m)                       1.965     3.500
        Upper Temp (C)                  201.2     24.0
        Lower Temp (C)                  54.9      24.0
        HRR (kW)                        5000.0    0.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 43 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 655.0 Seconds.
FED thermal (incap) exceeded 0.3 at 346.0 Seconds.
Upper Layer Temperature Exceeds 200 deg C at 1103.0 Seconds.
Visibility at 2m above floor reduced to 10 m at 325.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 325.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 49.8 seconds.
====================================================================
```

Scenario 7

```
Thursday, March 07,2013,10:31 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 7\Level 4
OC 07.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                  25.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  1  has a flat ceiling.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                             810.0
         Wall Conductivity (W/m.K) =                        0.160
         Wall Emissivity =                                  0.88
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

Room  2  :
         Room Length (m) =                                  25.00
         Room Width (m) =                                   20.00
         Maximum Room Height (m) =                          3.50
         Minimum Room Height (m) =                          3.50
         Floor Elevation (m) =                              12.000
         Room  2  has a flat ceiling.

         Wall Surface is concrete
         Wall Density (kg/m3) =                             2300.0
         Wall Conductivity (W/m.K) =                        1.200
         Wall Emissivity =                                  0.50
         Wall Thickness (mm) =                              100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                          2300.0
         Ceiling Conductivity (W/m.K) =                     1.200
         Ceiling Emissivity =                               0.50
         Ceiling Thickness (mm) =                           100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                            2300.0
         Floor Conductivity (W/m.K) =                       1.200
         Floor Emissivity =                                 0.50
         Floor Thickness = (mm)                             100.0

====================================================================
Wall Vents
====================================================================
From room  1  to  2 , Vent No 1
                   Vent Width (m) =                         0.006
                   Vent Height (m) =                        2.000
                   Vent Sill Height (m) =                   0.000
```

```
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to  2 , Vent No 2
                   Vent Width (m) =                        0.006
                   Vent Height (m) =                       2.000
                   Vent Sill Height (m) =                  0.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 1
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                        1.200
                   Vent Height (m) =                       1.000
                   Vent Sill Height (m) =                  1.000
                   Vent Soffit Height (m) =                2.000
                   Opening Time (sec) =                    0
                   Closing Time (sec) =                    0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                        24.0
Exterior Temp (C) =                                        35.0
Relative Humidity (%) =                                    50

====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =             2.00
Occupant Activity Level =                                  Light
Visibility calculations assume:                            reflective signs
FED Start Time (sec)                                       0
FED End Time (sec)                                         1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)             0.097
         Detector Characteristic Length Number (m)         15.0
         Detector Sensitivity (%/ft)                       6.6
         Radial Distance from Plume (m)                    7.100
         Distance below Ceiling (m)                        0.025
         Detector response is based on OD inside the detector chamber.

====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                               3.000
         Start Time (sec) =                                87
         Maximum Cross-Fan Pressure Limit (Pa) =           50
         Number of Fans =                                  1
         Extract Rate per fan (m3/s) =                     6.00
Mechanical Ventilation not installed in Room 2

====================================================================
Description of the Fire
====================================================================
```

```
Radiant Loss Fraction =                                     0.30
CO Yield pre-flashover(g/g) =                               0.040
Soot Alpha Coefficient =                                    2.50
Smoke Epsilon Coefficient =                                 1.20
Smoke Emission Coefficient (1/m) =                          0.80
Characteristic Mass Loss per Unit Area (kg/s.m2) =          0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

              Located in Room                               1
              Energy Yield (kJ/g) =                         12.4
              CO2 Yield (kg/kg fuel) =                      1.190
              Soot Yield (kg/kg fuel) =                     0.015
              HCN Yield (kg/kg fuel) =                      0.000
              Fire Height (m) =                             0.000
              Fire Location =                               Centre

              Time (sec)                Heat Release (kW)
               0                        0
               11                       6
               22                       22
               33                       50
               44                       89
               54                       139
               65                       200
               76                       272
               87                       356
               98                       450
               109                      556
               120                      672
               131                      800
               141                      939
               152                      1089
               163                      1250
               174                      1422
               185                      1606
               196                      1800
               207                      2006
               218                      2222
               229                      2450
               239                      2689
               250                      2939
               261                      3200
               272                      3472
               283                      3756
               294                      4050
               305                      4356
               316                      4672
               326.5                    5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min    00 sec
         (0 sec)                        Room 1    Room 2    Outside

         Layer (m)                      3.500     3.500
         Upper Temp (C)                 24.0      24.0
         Lower Temp (C)                 24.0      24.0
         HRR (kW)                       0.0       0.0

2 min    00 sec
         (120 sec)                      Room 1    Room 2    Outside

         Layer (m)                      2.721     3.500
         Upper Temp (C)                 56.0      24.0
```

```
         Lower Temp (C)                24.6      24.0
         HRR (kW)                      672.2     0.0

4 min    00 sec
         (240 sec)                     Room 1    Room 2    Outside

         Layer (m)                     1.874     3.500
         Upper Temp (C)                119.1     24.0
         Lower Temp (C)                31.2      24.0
         HRR (kW)                      2711.6    0.0

6 min    00 sec
         (360 sec)                     Room 1    Room 2    Outside

         Layer (m)                     0.582     3.499
         Upper Temp (C)                197.3     24.4
         Lower Temp (C)                50.3      24.0
         HRR (kW)                      5000.0    0.0

8 min    00 sec
         (480 sec)                     Room 1    Room 2    Outside

         Layer (m)                     0.235     3.499
         Upper Temp (C)                231.6     24.0
         Lower Temp (C)                66.2      24.0
         HRR (kW)                      5000.0    0.0

10 min   00 sec
         (600 sec)                     Room 1    Room 2    Outside

         Layer (m)                     0.240     3.499
         Upper Temp (C)                241.9     24.0
         Lower Temp (C)                68.3      24.0
         HRR (kW)                      5000.0    0.0

12 min   00 sec
         (720 sec)                     Room 1    Room 2    Outside

         Layer (m)                     0.242     3.499
         Upper Temp (C)                247.4     24.0
         Lower Temp (C)                72.4      24.0
         HRR (kW)                      5000.0    0.0

14 min   00 sec
         (840 sec)                     Room 1    Room 2    Outside

         Layer (m)                     0.241     3.499
         Upper Temp (C)                251.9     24.0
         Lower Temp (C)                75.9      24.0
         HRR (kW)                      5000.0    0.0

16 min   00 sec
         (960 sec)                     Room 1    Room 2    Outside

         Layer (m)                     0.240     3.499
         Upper Temp (C)                255.6     24.0
         Lower Temp (C)                77.4      24.0
         HRR (kW)                      5000.0    0.0

18 min   00 sec
         (1080 sec)                    Room 1    Room 2    Outside

         Layer (m)                     0.238     3.499
         Upper Temp (C)                258.9     24.0
         Lower Temp (C)                80.1      24.0
         HRR (kW)                      5000.0    0.0

20 min   00 sec
         (1200 sec)                    Room 1    Room 2    Outside

         Layer (m)                     0.236     3.499
         Upper Temp (C)                262.0     24.0
         Lower Temp (C)                82.7      24.0
         HRR (kW)                      5000.0    0.0
```

```
====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 87 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 444.0 Seconds.
FED thermal (incap) exceeded 0.3 at 282.0 Seconds.
Upper Layer Temperature Exceeds 200 deg C at 366.0 Seconds.
Visibility at 2m above floor reduced to 10 m at 221.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 221.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 49.4 seconds.
====================================================================
```

Scenario 8

```
Thursday, March 07,2013,11:06 PM
Input Filename : C:\Users\Jack\Documents\02. University Courses\Master of Engineering
Fire Engineering\08 ENFE 690 Project\Modelling\Original Construction\Scenario 8\Level 4
OC 08.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2012.1)

Level 4 of Hospital A

====================================================================
Description of Rooms
====================================================================
Room  1  : Level 4
         Room Length (m) =                                 25.00
         Room Width (m) =                                  20.00
         Maximum Room Height (m) =                         3.50
         Minimum Room Height (m) =                         3.50
         Floor Elevation (m) =                             12.000
         Room  1  has a flat ceiling.

         Wall Surface is plasterboard (Australia)
         Wall Density (kg/m3) =                            810.0
         Wall Conductivity (W/m.K) =                       0.160
         Wall Emissivity =                                 0.88
         Wall Thickness (mm) =                             100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                         2300.0
         Ceiling Conductivity (W/m.K) =                    1.200
         Ceiling Emissivity =                              0.50
         Ceiling Thickness (mm) =                          100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                           2300.0
         Floor Conductivity (W/m.K) =                      1.200
         Floor Emissivity =                                0.50
         Floor Thickness = (mm)                            100.0

Room  2  :
         Room Length (m) =                                 25.00
         Room Width (m) =                                  20.00
         Maximum Room Height (m) =                         3.50
         Minimum Room Height (m) =                         3.50
         Floor Elevation (m) =                             12.000
         Room  2  has a flat ceiling.

         Wall Surface is concrete
         Wall Density (kg/m3) =                            2300.0
         Wall Conductivity (W/m.K) =                       1.200
         Wall Emissivity =                                 0.50
         Wall Thickness (mm) =                             100.0

         Ceiling Surface is concrete
         Ceiling Density (kg/m3) =                         2300.0
         Ceiling Conductivity (W/m.K) =                    1.200
         Ceiling Emissivity =                              0.50
         Ceiling Thickness (mm) =                          100.0

         Floor Surface is concrete
         Floor Density (kg/m3) =                           2300.0
         Floor Conductivity (W/m.K) =                      1.200
         Floor Emissivity =                                0.50
         Floor Thickness = (mm)                            100.0

====================================================================
Wall Vents
====================================================================
From room  1  to  2 , Vent No 1
```

```
                   Vent Width (m) =                       0.006
                   Vent Height (m) =                      2.000
                   Vent Sill Height (m) =                 0.000
                   Vent Soffit Height (m) =               2.000
                   Opening Time (sec) =                   0
                   Closing Time (sec) =                   0

From room  1  to  2 , Vent No 2
                   Vent Width (m) =                       0.006
                   Vent Height (m) =                      2.000
                   Vent Sill Height (m) =                 0.000
                   Vent Soffit Height (m) =               2.000
                   Opening Time (sec) =                   0
                   Closing Time (sec) =                   0

From room  1  to outside, Vent No 1
                   Vent Width (m) =                       1.200
                   Vent Height (m) =                      1.000
                   Vent Sill Height (m) =                 1.000
                   Vent Soffit Height (m) =               2.000
                   Opening Time (sec) =                   0
                   Closing Time (sec) =                   0

From room  1  to outside, Vent No 2
                   Vent Width (m) =                       1.200
                   Vent Height (m) =                      1.000
                   Vent Sill Height (m) =                 1.000
                   Vent Soffit Height (m) =               2.000
                   Opening Time (sec) =                   0
                   Closing Time (sec) =                   0

====================================================================
Ceiling/Floor Vents
====================================================================
====================================================================
Ambient Conditions
====================================================================
Interior Temp (C) =                                       24.0
Exterior Temp (C) =                                       35.0
Relative Humidity (%) =                                   50

====================================================================
Tenability Parameters
====================================================================
Monitoring Height for Visibility and FED (m) =            2.00
Occupant Activity Level =                                 Light
Visibility calculations assume:                           reflective signs
FED Start Time (sec)                                      0
FED End Time (sec)                                        1200

====================================================================
Sprinkler / Detector Parameters
====================================================================
No thermal detector or sprinkler installed.
Smoke Detector in Room 1
         Smoke Optical Density for Alarm (1/m)            0.097
         Detector Characteristic Length Number (m)        15.0
         Detector Sensitivity (%/ft)                      6.6
         Radial Distance from Plume (m)                   7.100
         Distance below Ceiling (m)                       0.025
         Detector response is based on OD inside the detector chamber.

====================================================================
Mechanical Ventilation (to/from outside)
====================================================================
Mechanical Ventilation installed in Room 1
         Use fan curve
         Fan Elevation (m) =                              3.000
         Start Time (sec) =                               87
         Maximum Cross-Fan Pressure Limit (Pa) =          50
         Number of Fans =                                 2
         Extract Rate per fan (m3/s) =                    10.00
Mechanical Ventilation installed in Room 2
         Do not use fan curve
```

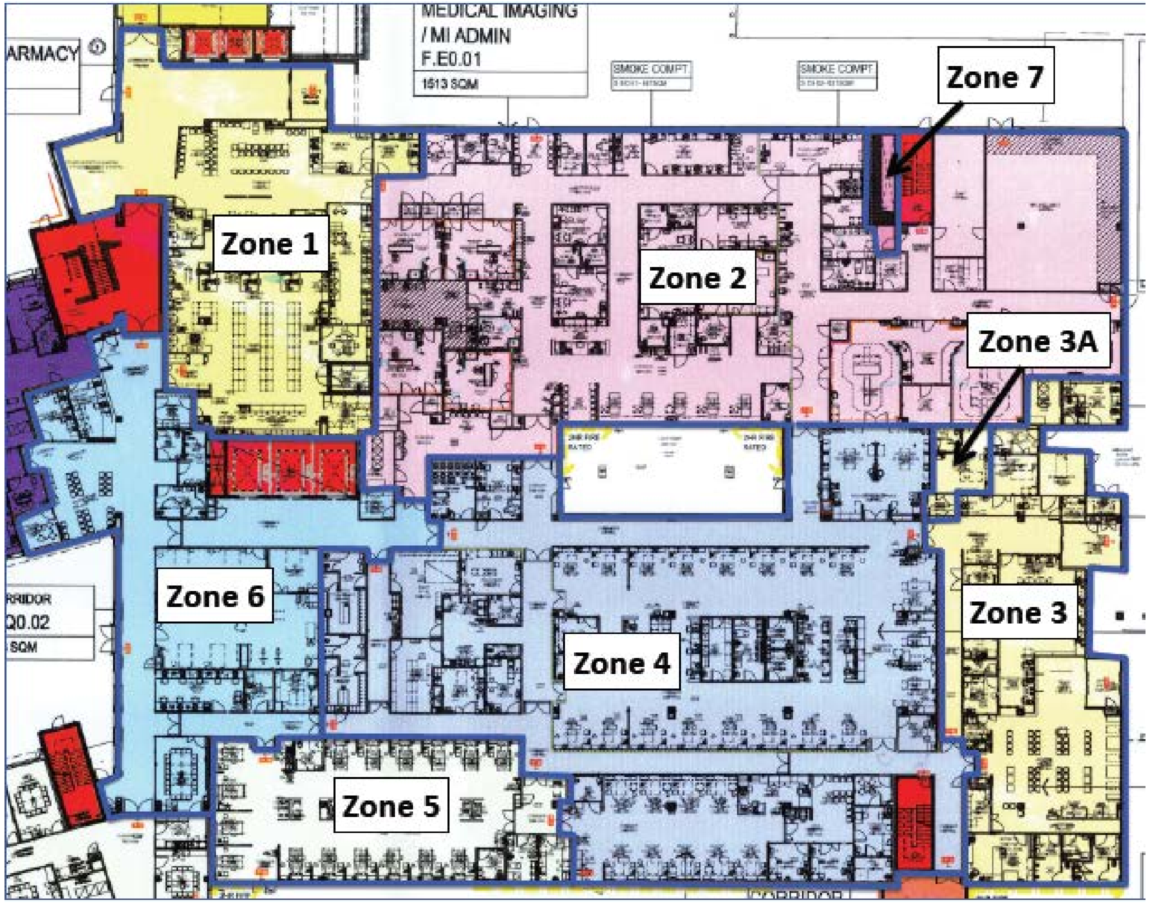
```
        Fan Elevation (m) =                                 3.000
        Start Time (sec) =                                  0
        Maximum Cross-Fan Pressure Limit (Pa) =             50
        Number of Fans =                                    1
        Extract Rate per fan (m3/s) =                       0.00

====================================================================
Description of the Fire
====================================================================
Radiant Loss Fraction =                                     0.30
CO Yield pre-flashover(g/g) =                               0.040
Soot Alpha Coefficient =                                    2.50
Smoke Epsilon Coefficient =                                 1.20
Smoke Emission Coefficient (1/m) =                          0.80
Characteristic Mass Loss per Unit Area (kg/s.m2) =          0.021
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

             Located in Room                                1
             Energy Yield (kJ/g) =                          12.4
             CO2 Yield (kg/kg fuel) =                       1.190
             Soot Yield (kg/kg fuel) =                      0.015
             HCN Yield (kg/kg fuel) =                       0.000
             Fire Height (m) =                              0.000
             Fire Location =                                Centre

             Time (sec)                Heat Release (kW)
              0                        0
              11                       6
              22                       22
              33                       50
              44                       89
              54                       139
              65                       200
              76                       272
              87                       356
              98                       450
              109                      556
              120                      672
              131                      800
              141                      939
              152                      1089
              163                      1250
              174                      1422
              185                      1606
              196                      1800
              207                      2006
              218                      2222
              229                      2450
              239                      2689
              250                      2939
              261                      3200
              272                      3472
              283                      3756
              294                      4050
              305                      4356
              316                      4672
              326.5                    5000

====================================================================
Postflashover Inputs
====================================================================
Postflashover model is OFF.


====================================================================
Results from Fire Simulation
====================================================================

0 min   00 sec
        (0 sec)                        Room 1    Room 2    Outside

        Layer (m)                      3.500     3.500
```

```
         Upper Temp (C)              24.0      24.0
         Lower Temp (C)              24.0      24.0
         HRR (kW)                    0.0       0.0

2 min    00 sec
         (120 sec)                   Room 1    Room 2    Outside

         Layer (m)                   2.750     3.500
         Upper Temp (C)              56.2      24.0
         Lower Temp (C)              25.0      24.0
         HRR (kW)                    672.2     0.0

4 min    00 sec
         (240 sec)                   Room 1    Room 2    Outside

         Layer (m)                   2.196     3.500
         Upper Temp (C)              121.1     24.0
         Lower Temp (C)              33.6      24.0
         HRR (kW)                    2711.6    0.0

6 min    00 sec
         (360 sec)                   Room 1    Room 2    Outside

         Layer (m)                   1.970     3.500
         Upper Temp (C)              185.7     24.0
         Lower Temp (C)              42.6      24.0
         HRR (kW)                    5000.0    0.0

8 min    00 sec
         (480 sec)                   Room 1    Room 2    Outside

         Layer (m)                   1.970     3.500
         Upper Temp (C)              193.8     24.0
         Lower Temp (C)              48.1      24.0
         HRR (kW)                    5000.0    0.0

10 min   00 sec
         (600 sec)                   Room 1    Room 2    Outside

         Layer (m)                   1.966     3.500
         Upper Temp (C)              197.6     24.0
         Lower Temp (C)              50.6      24.0
         HRR (kW)                    5000.0    0.0

12 min   00 sec
         (720 sec)                   Room 1    Room 2    Outside

         Layer (m)                   1.964     3.500
         Upper Temp (C)              200.5     24.0
         Lower Temp (C)              52.3      24.0
         HRR (kW)                    5000.0    0.0

14 min   00 sec
         (840 sec)                   Room 1    Room 2    Outside

         Layer (m)                   1.962     3.500
         Upper Temp (C)              202.7     24.0
         Lower Temp (C)              53.6      24.0
         HRR (kW)                    5000.0    0.0

16 min   00 sec
         (960 sec)                   Room 1    Room 2    Outside

         Layer (m)                   1.960     3.500
         Upper Temp (C)              204.7     24.0
         Lower Temp (C)              54.7      24.0
         HRR (kW)                    5000.0    0.0

18 min   00 sec
         (1080 sec)                  Room 1    Room 2    Outside

         Layer (m)                   1.959     3.500
         Upper Temp (C)              206.4     24.0
         Lower Temp (C)              55.7      24.0
```

```
        HRR (kW)                      5000.0    0.0

20 min  00 sec
        (1200 sec)                    Room 1    Room 2    Outside

        Layer (m)                     1.957     3.500
        Upper Temp (C)                208.0     24.0
        Lower Temp (C)                56.6      24.0
        HRR (kW)                      5000.0    0.0


====================================================================
Event Log
====================================================================
Smoke Detector in Room 1 operated at 87 seconds.

====================================================================
Summary of End-Point Conditions in Room of Fire Origin
====================================================================
FED asphyxiant gases (incap) Exceeded 0.3 at 549.0 Seconds.
FED thermal (incap) exceeded 0.3 at 342.0 Seconds.
Upper Layer Temperature Exceeds 200 deg C at 699.0 Seconds.
Visibility at 2m above floor reduced to 10 m at 323.0 Seconds.
Temperature at 2m above floor has reached 60 deg C at 323.0 Seconds.

====================================================================
Initial Time-Step = 1.00 seconds.
Computer Run-Time = 48.9 seconds.
====================================================================
```

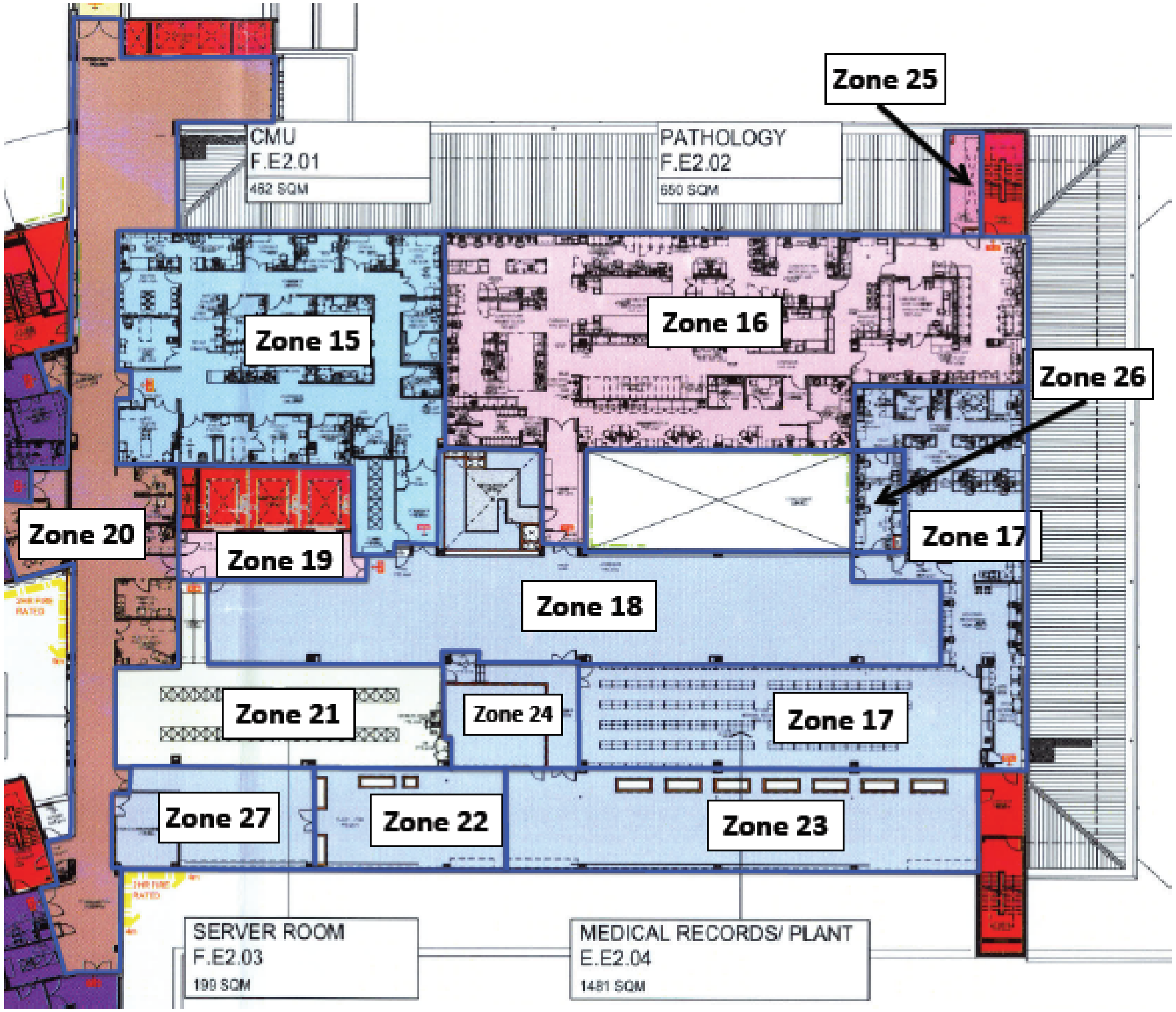
APPENDIX D HOSPITAL B COMPARTMENTATION PLANS

Building E Level 0

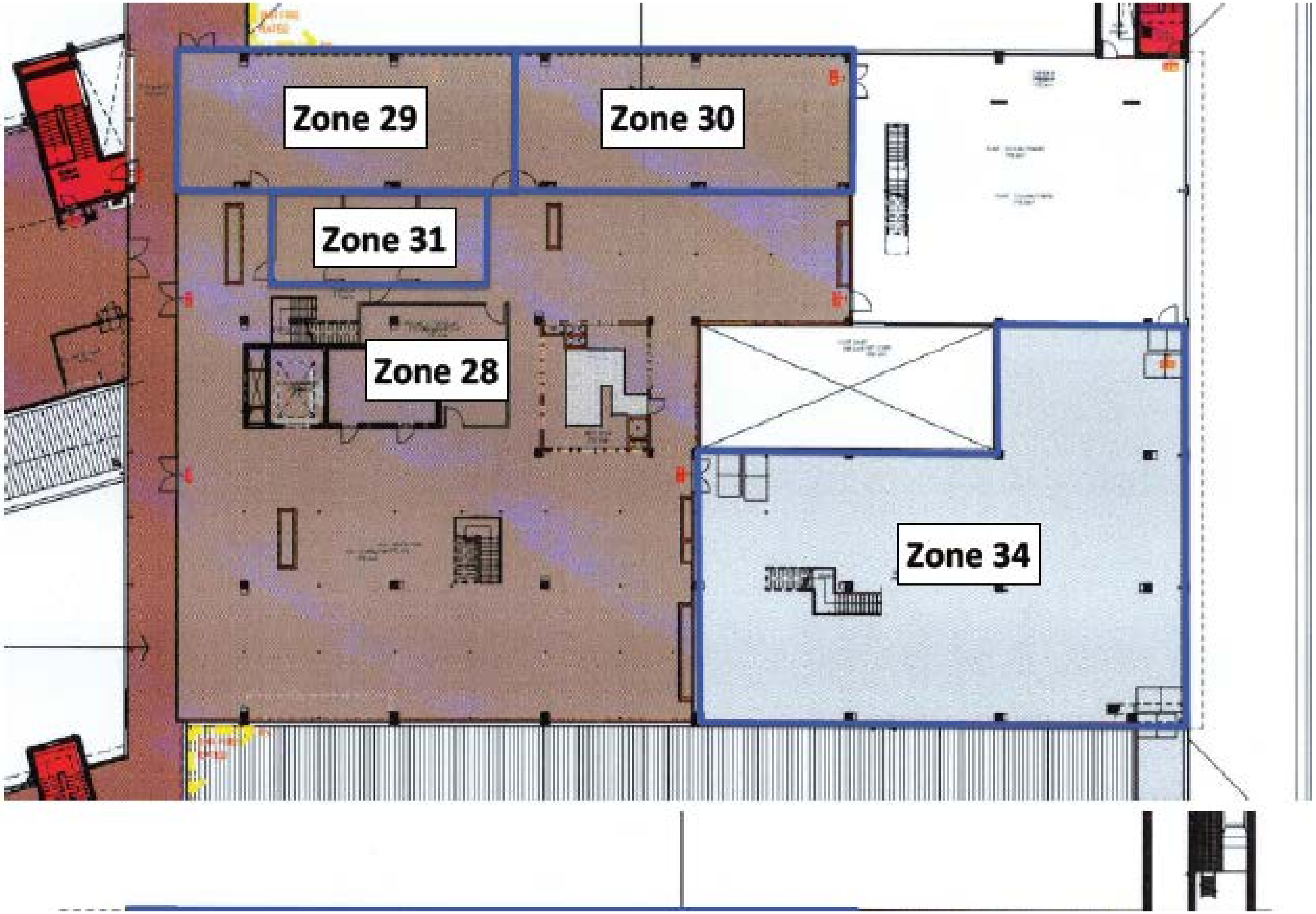


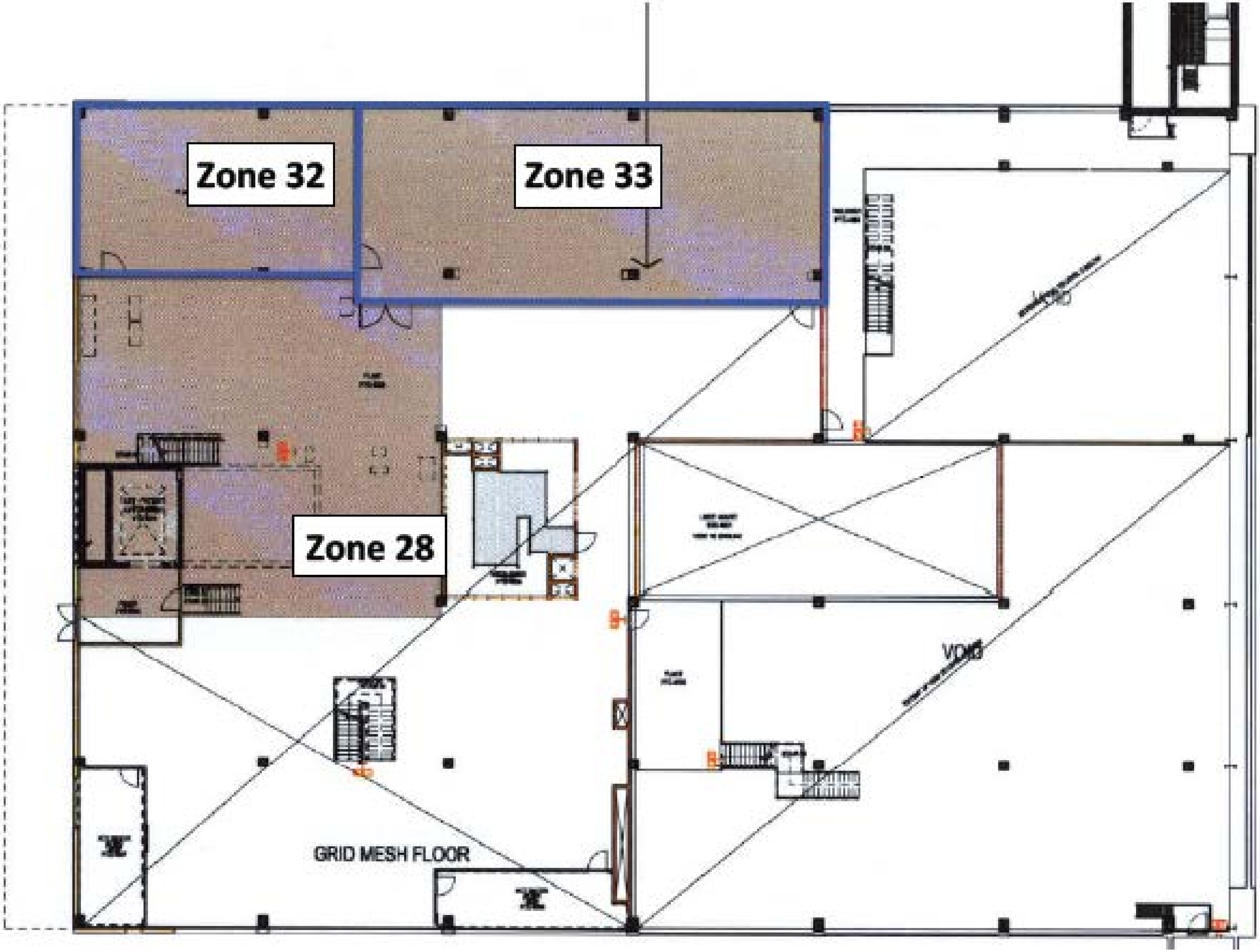
Building E Level 1

Building E Level 2



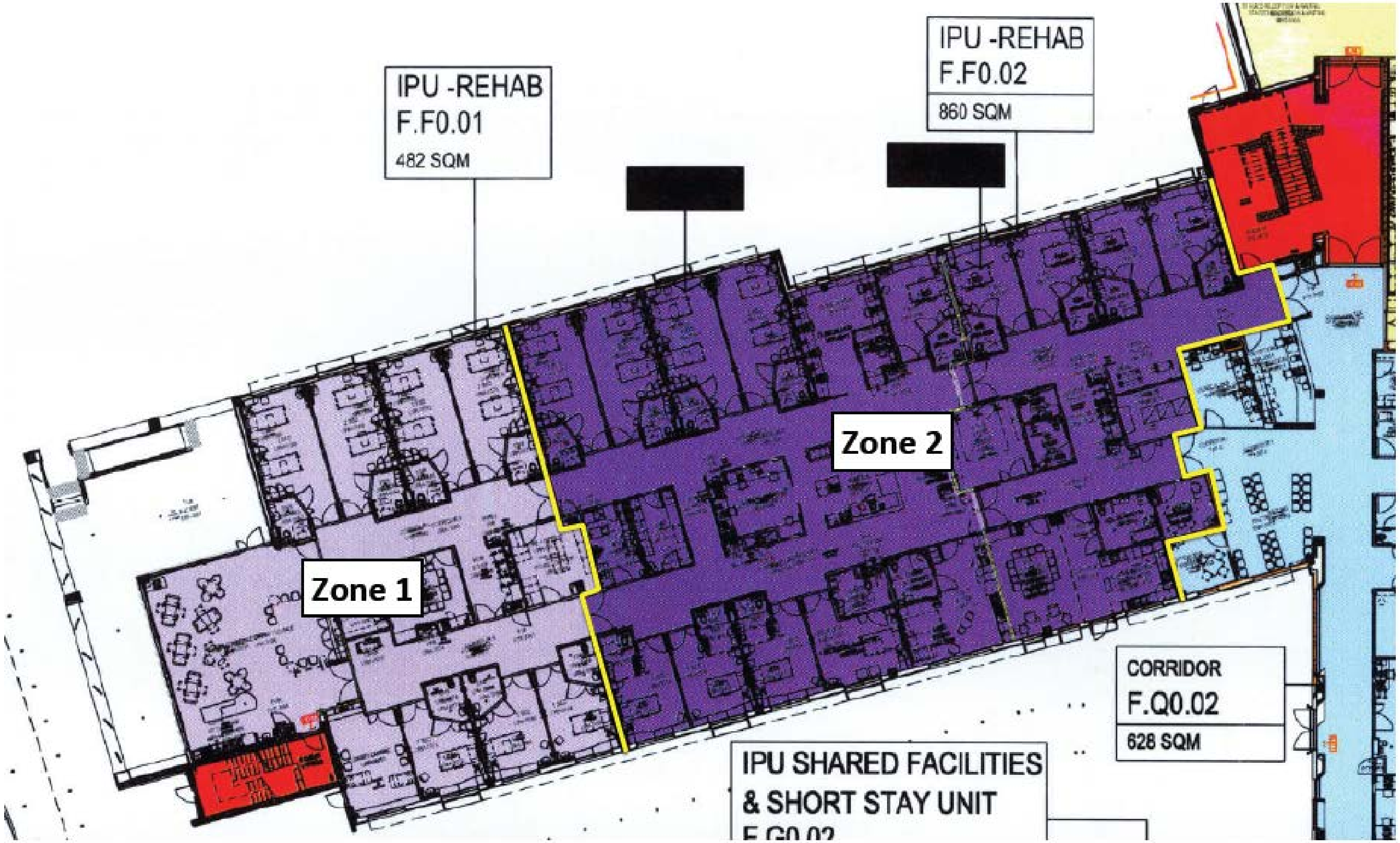
Building E Level 3


Zone 29
Zone 30
Zone 31
Zone 28
Zone 34

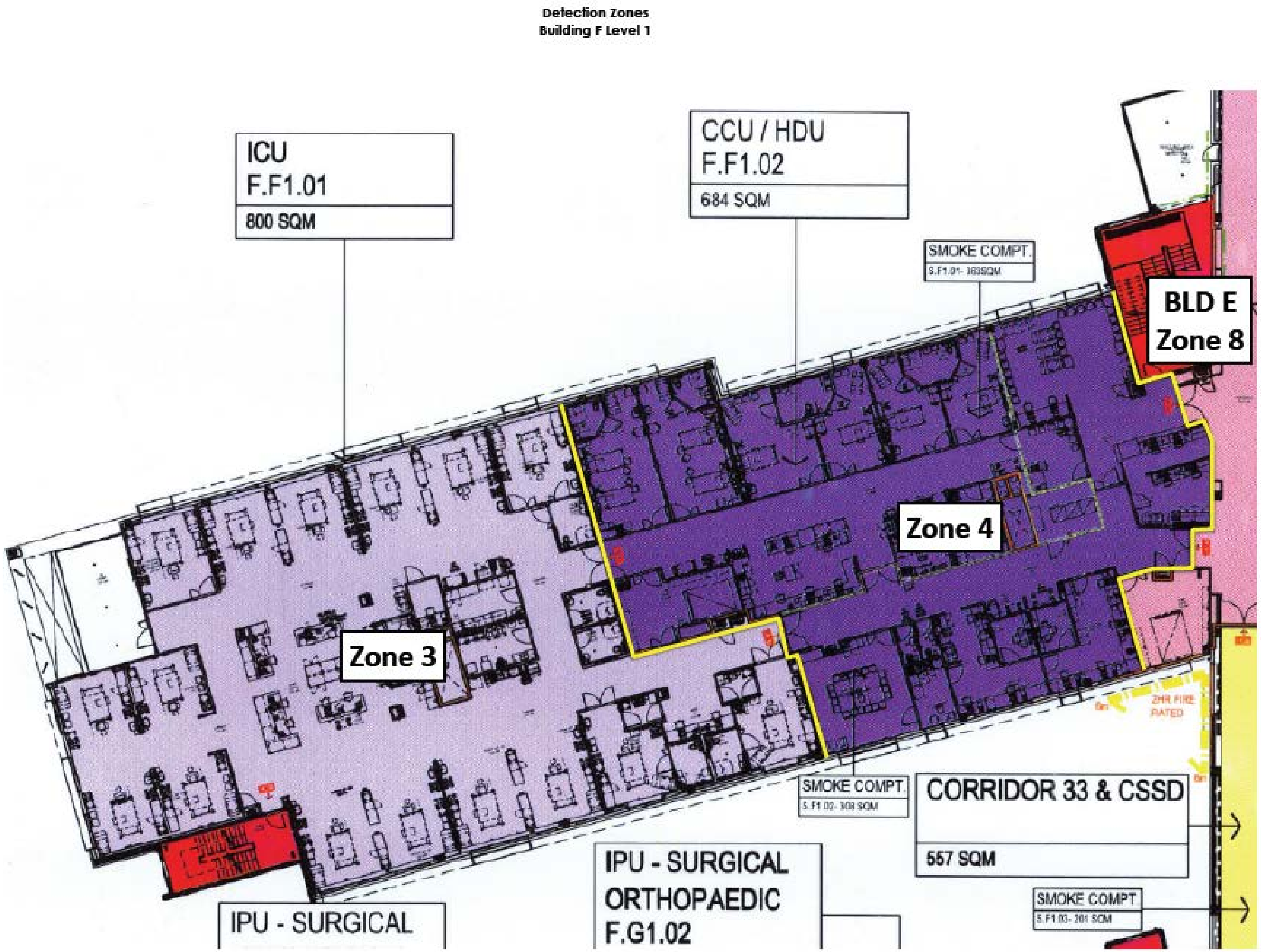

Zone 32
Zone 33
Zone 28
GRID MESH FLOOR
VOID

Building F Level 0

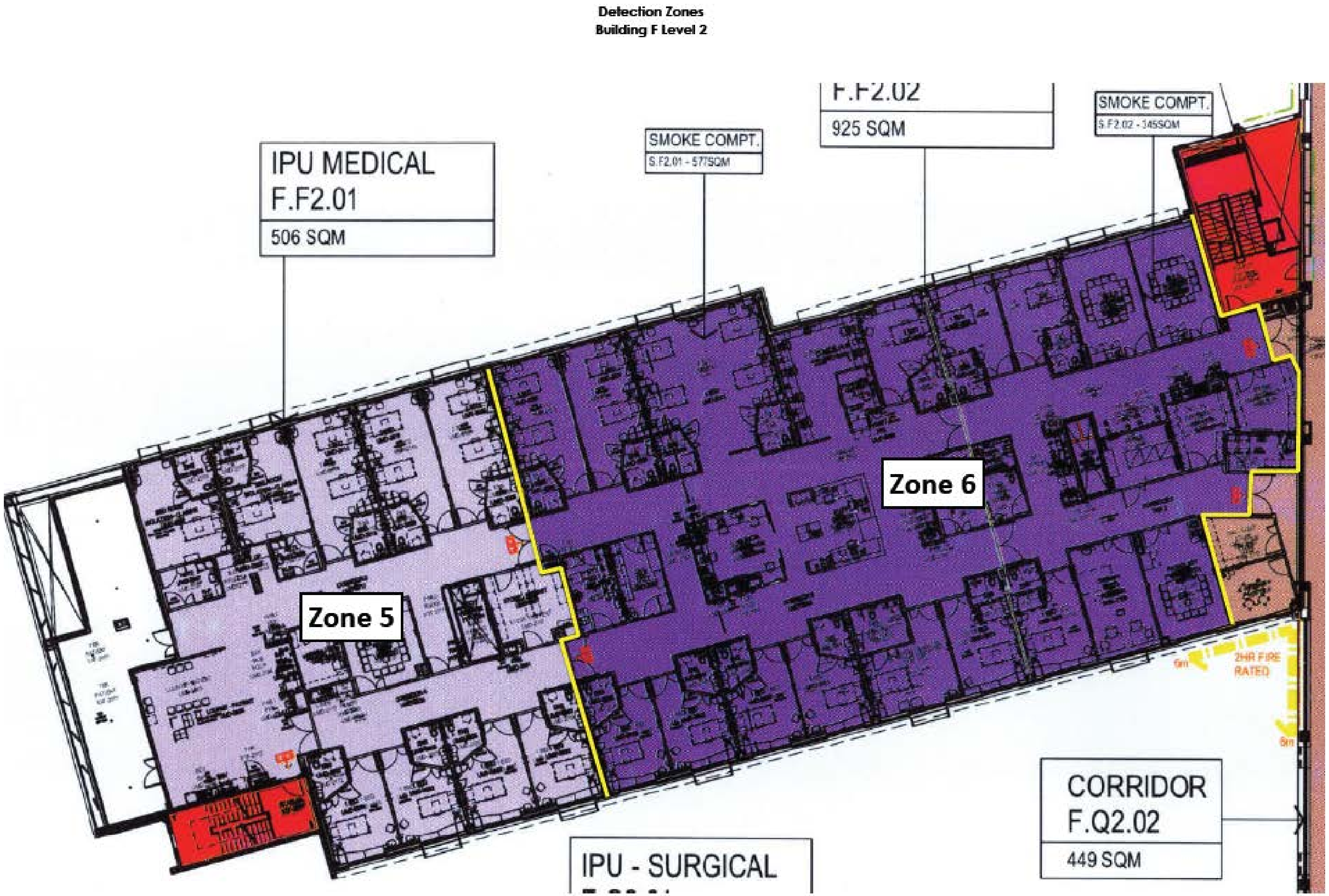
Detection Zones
Building F Level 0



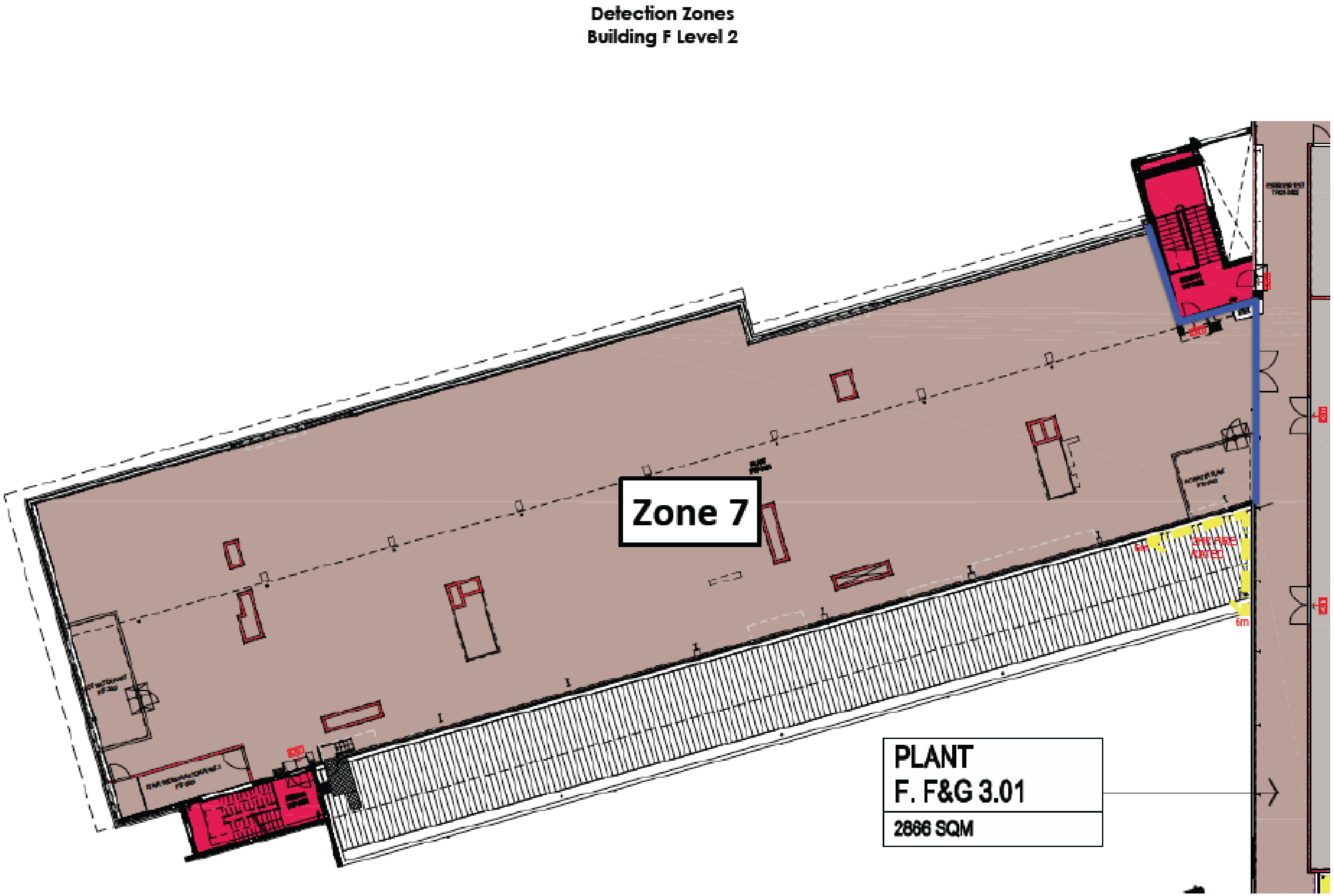
Building F Level 1



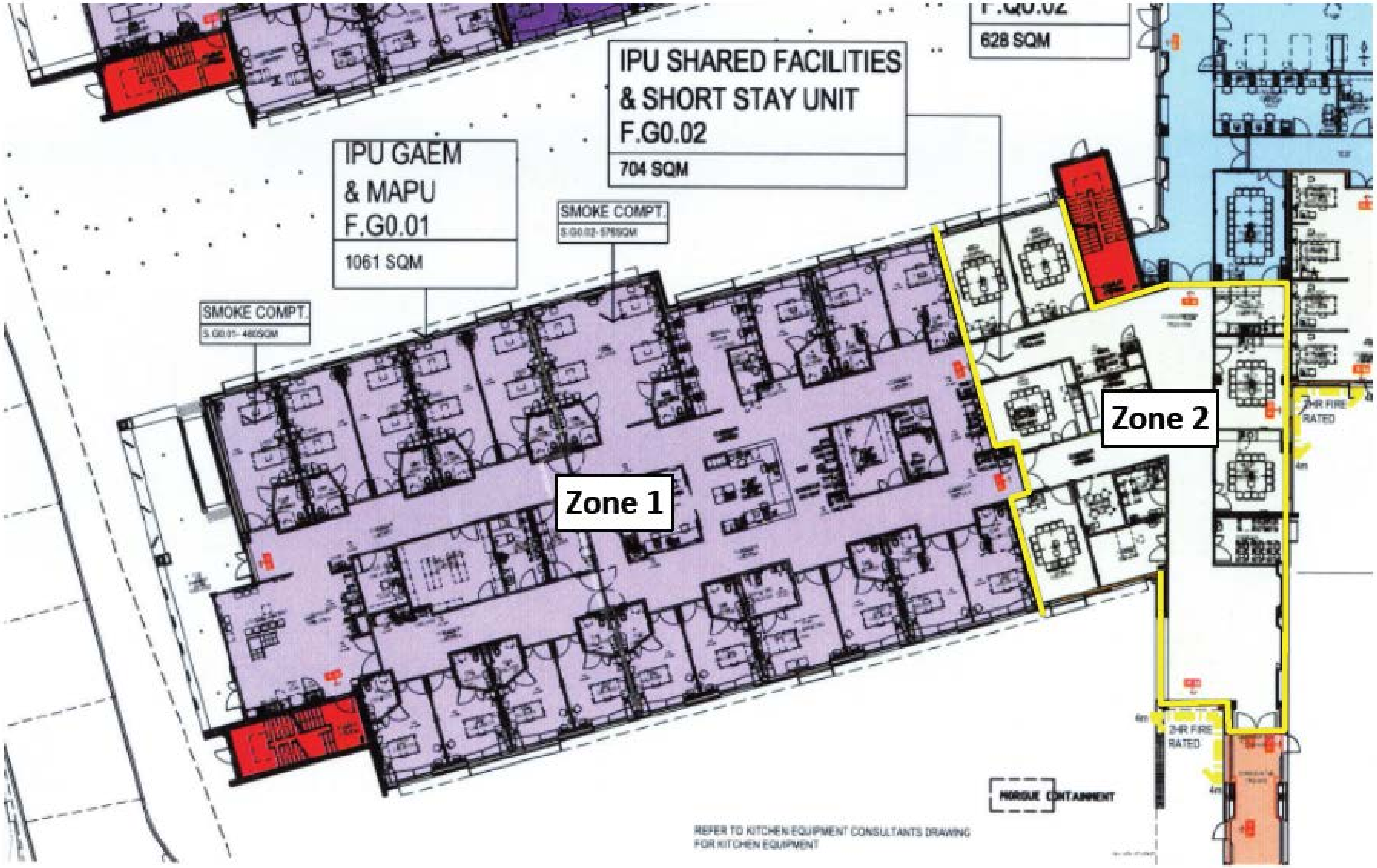
Building F Level 2



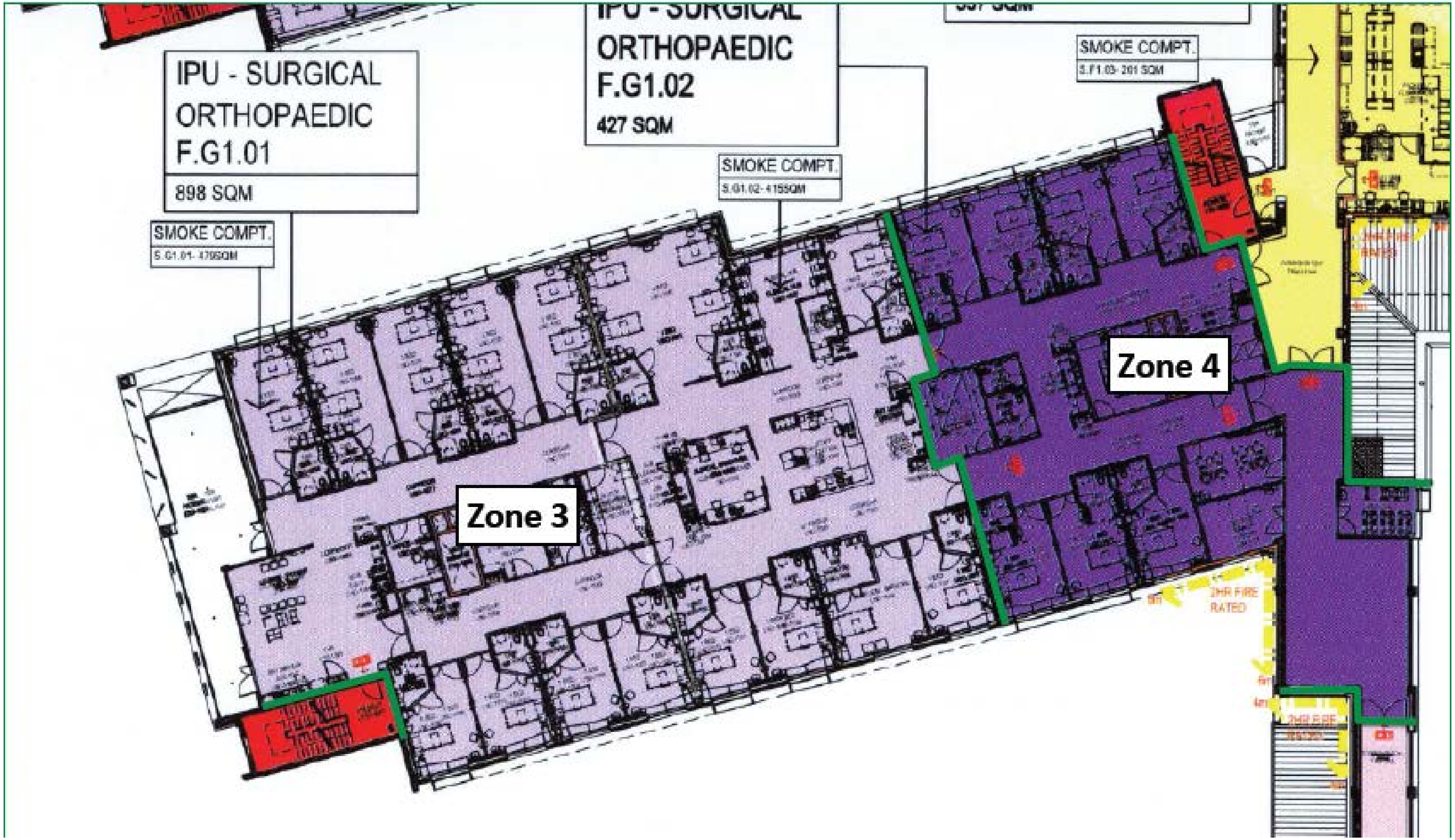
Building F Level 3



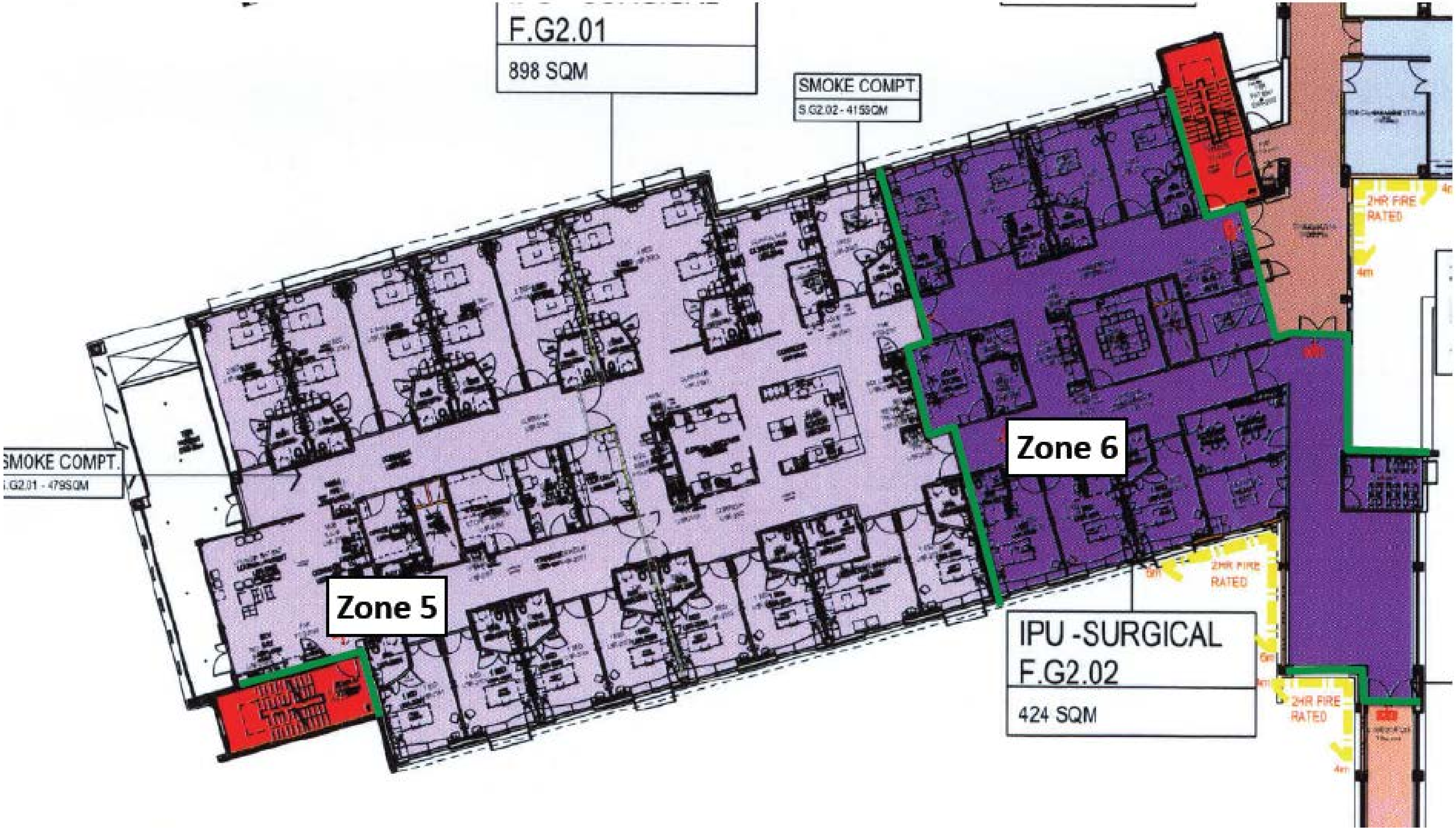
Building G Level 0



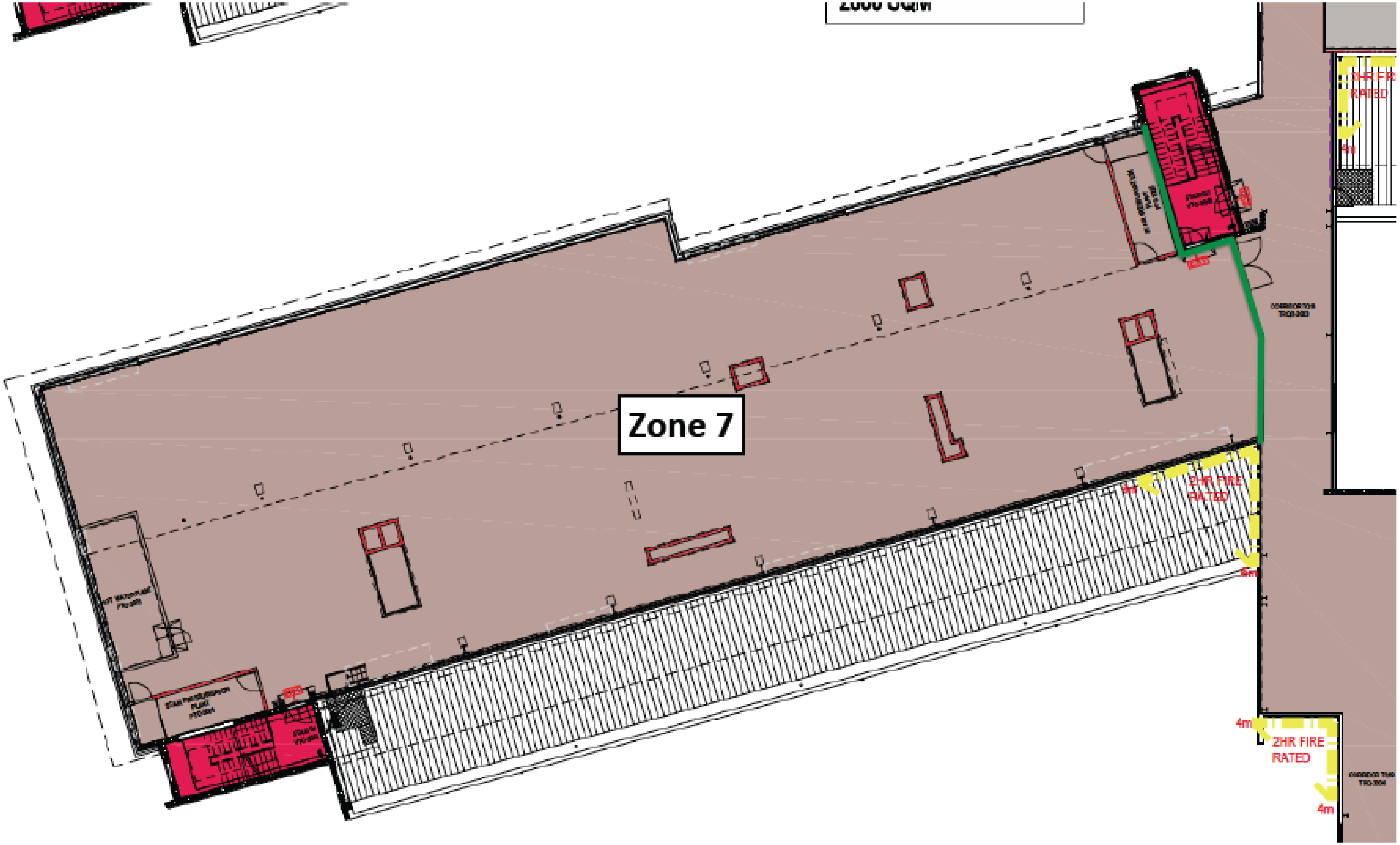
Building G Level 1



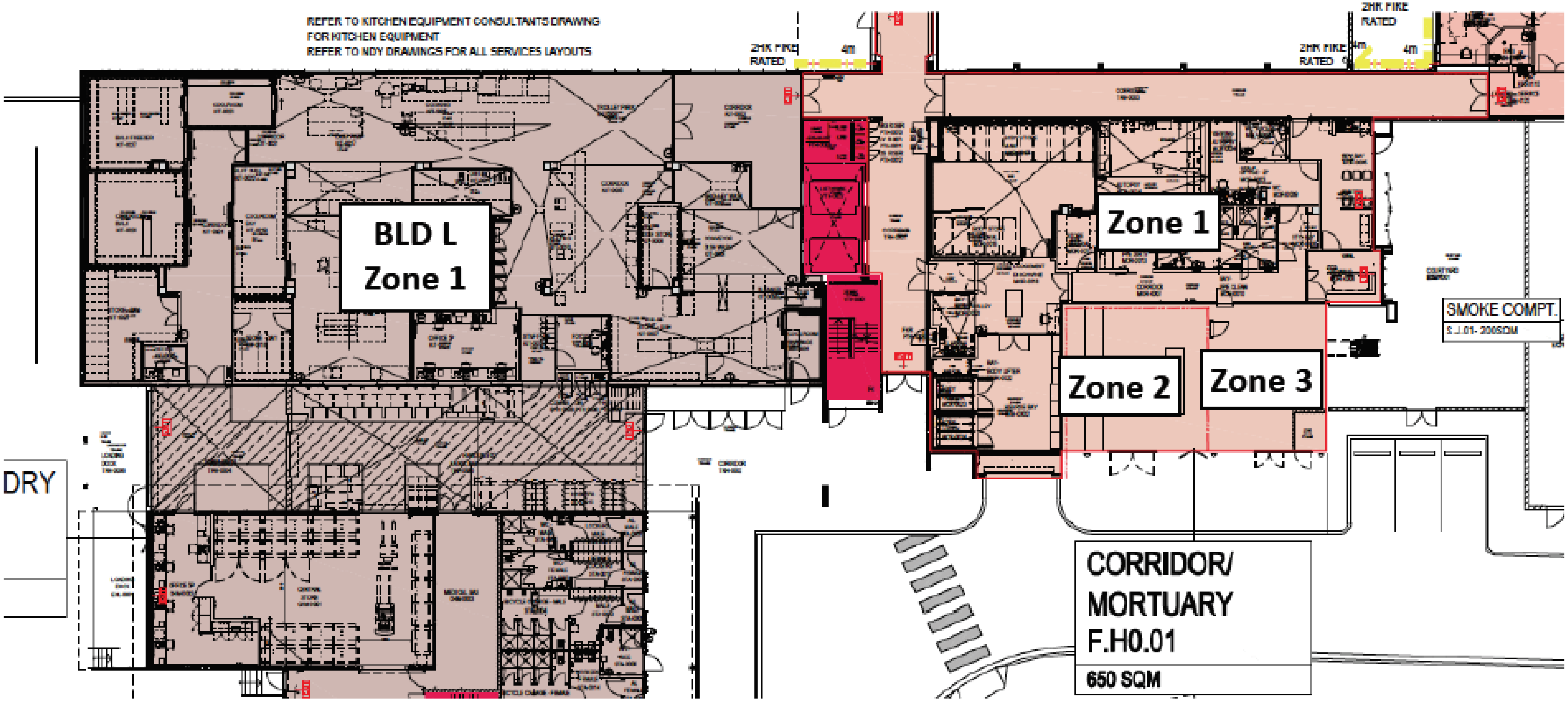
Building G Level 2



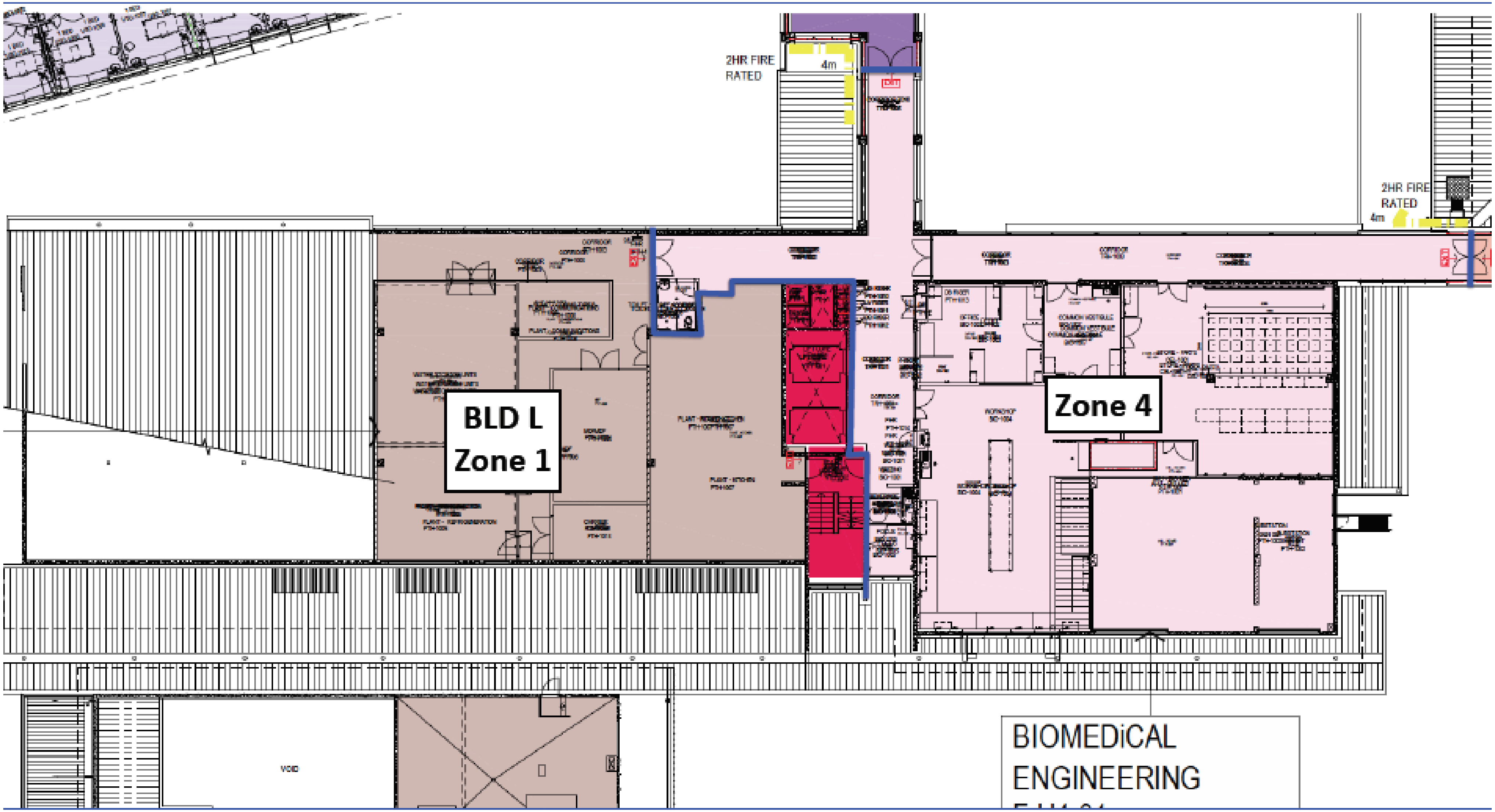
Building G Level 3



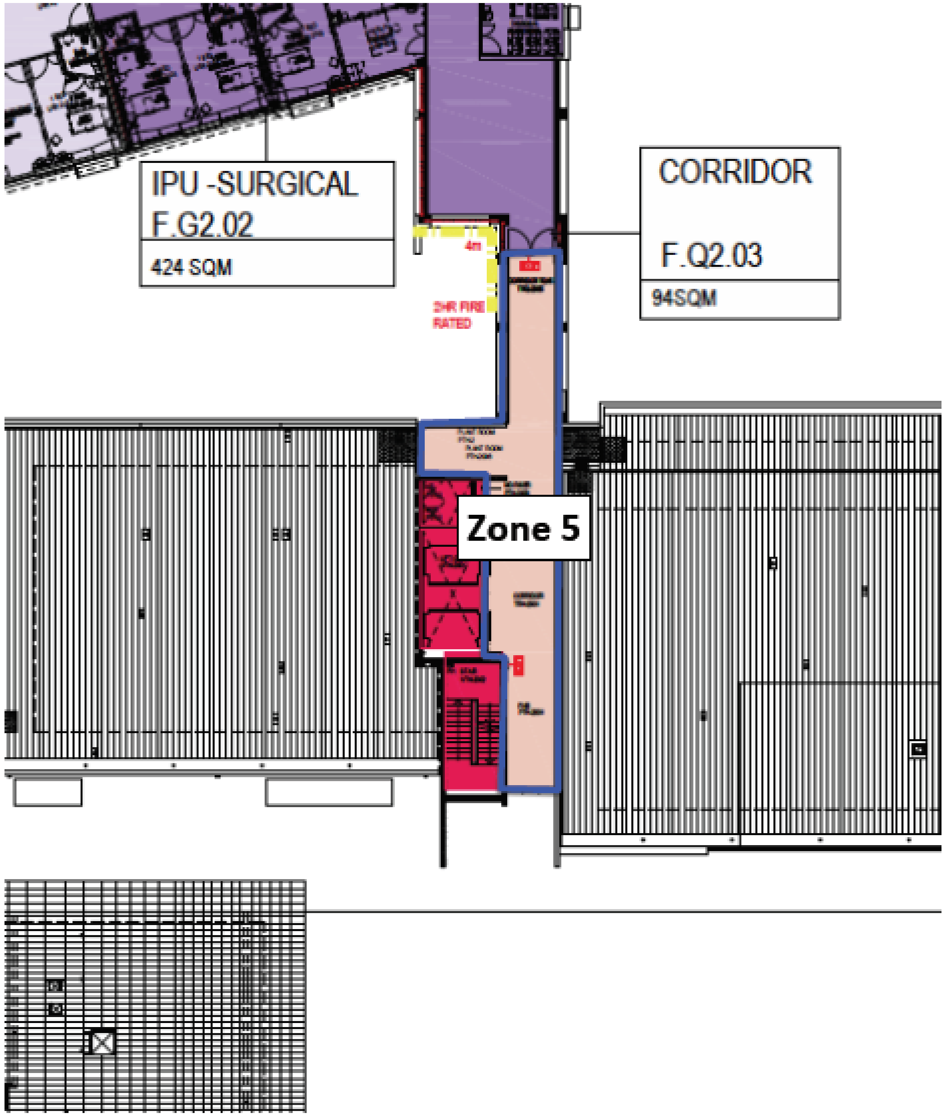
Building H Level 0



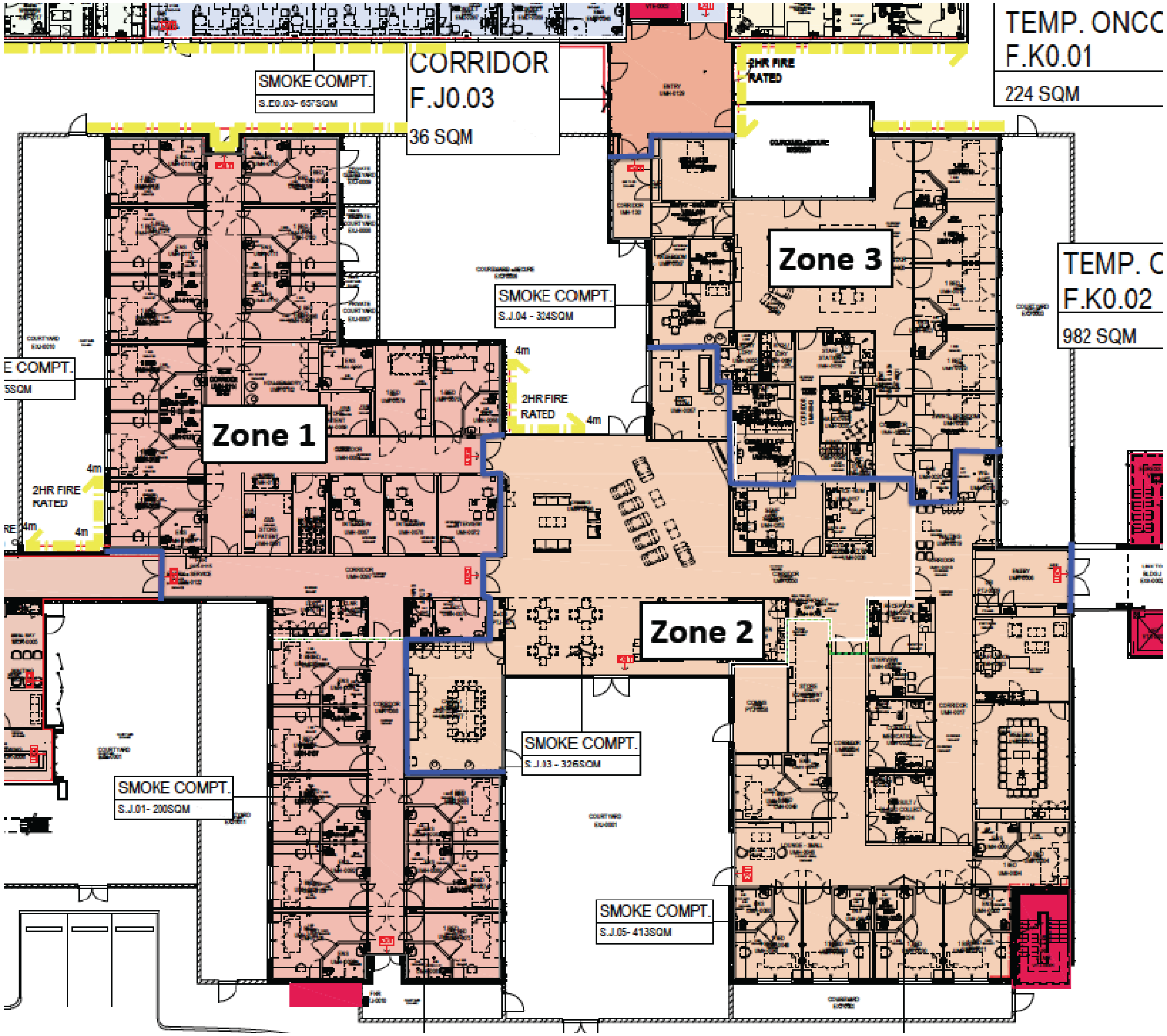
Building H Level 1



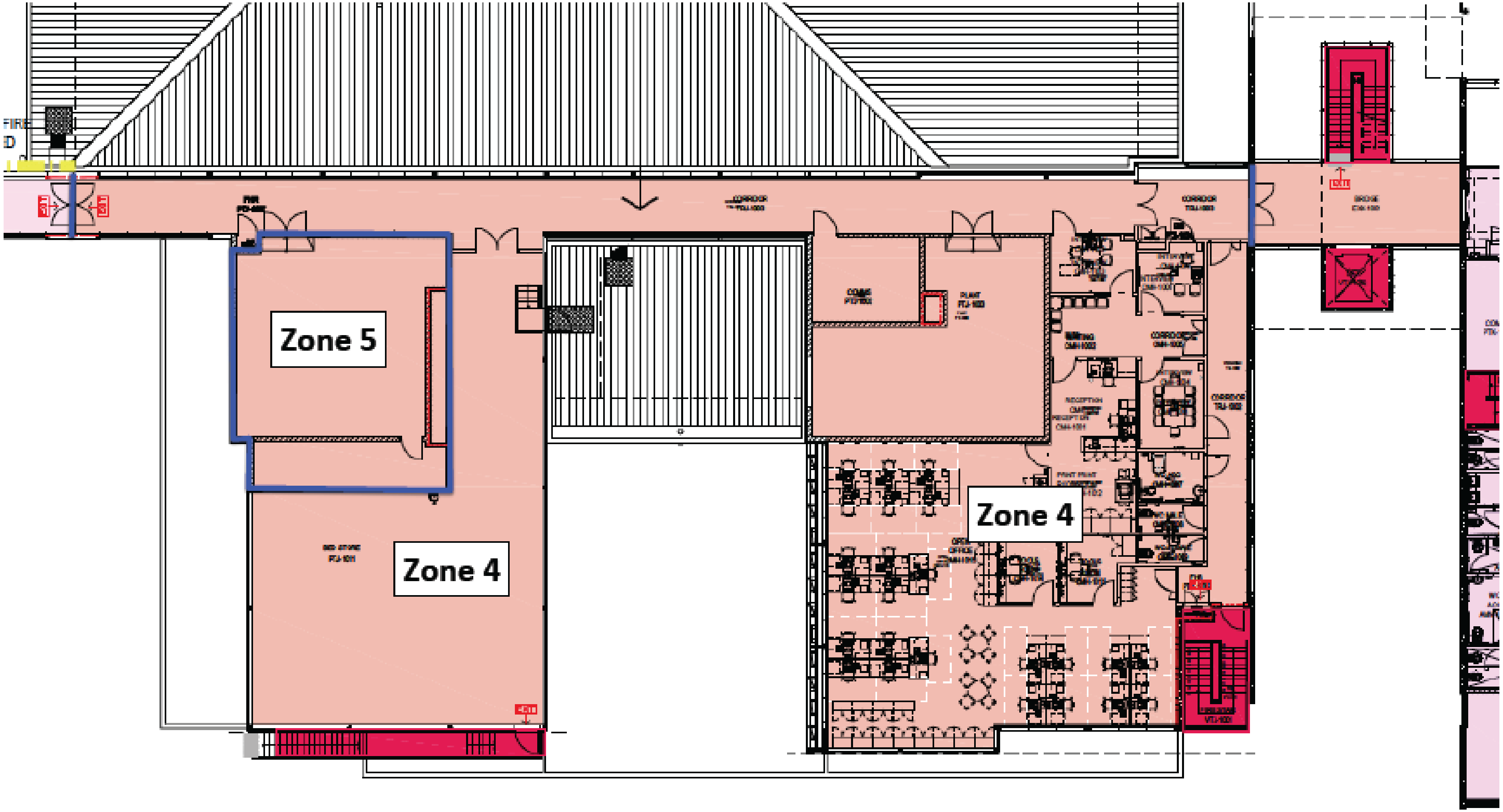
Building H Level 2



Building J Level 0



Building J Level 1



APPENDIX E SAMPLE OF FIRE MATRIX FOR HOSPITAL B

Line	Device Location	Device	Associated Plant	MSSB	Level 1															Bld F Level 1 Zone 3	All Zones Level 0	All Zones Level 2	Level 3 Zone 1
								Theatres															
					Zone 8	Zone 9	Zone 10	10.1	10.2	10.3	10.4	10.5	10.6	10.7	Zone 11	Zone 12	Zone 13	Zone 14	Lift Core				
1		**Air Handling Units**																					
2	**Level 3**	AHU-E-3-1.1		MSSB-E-3D/E	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
3	**Level 3**	AHU-E-3-1.2		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
4	**Level 3**	AHU-E-3-1.3		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
5	**Level 3**	AHU-E-3-1.4		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
6	**Level 3**	AHU-E-3-1.5		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
7	**Level 3**	AHU-E-3-1.6		MSSB-E-3D/E	On	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
8	**Level 3**	AHU-E-3-1.7		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
9	**Level 3**	AHU-E-3-1.8		MSSB-E-3D/E	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
10	**Level 3**	AHU-E-3-1.9		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
11	**Level 3**	AHU-E-3-1.10		MSSB-E-3D/E	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
12	**Level 2**	AHU-E-2.1.1		MSSB-E-2A/E	On	On	On	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On
13	**Level 2**	AHU-E-2.1.2		MSSB-E-2A/E	On	On	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
14	**Level 2**	AHU-E-2.1.3		MSSB-E-2A/E	On	On	On	On	On	Off	On	On	On	On	On	On	On	On	On	On	On	On	On
15	**Level 2**	AHU-E-2.1.4		TBA	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On	On	On	On	On
16	**Level 2**	AHU-E-2.1.5		MSSB-E-2B/E	On	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On	On	On	On
17	**Level 2**	AHU-E-2.1.6		MSSB-E-2B/E	On	On	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On	On	On
18	**Level 2**	AHU-E-2.1.7		MSSB-E-2B/E	On	On	On	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On	On
19	**Level 2**	AHU-E-2.1.8		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On
20	**Level 2**	AHU-E-2.1.9		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On
21	**Level 2**	AHU-E-2.1.10		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	Off	On	On	On	On	On	On	On	On
22		**Exhaust Fans**																					
23	**Level 3**	GEX-E.3.1.1		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
24	**Level 3**	GEX-E.3.1.2		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
25	**Level 3**	GEX-E.3.1.3		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
26	**Level 3**	GEX-E.3.1.4		MSSB-E-2C/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off
27	**Level 2**	GEX-E-2.2.4		MSSB-E-2A/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
28	**Level 2**	GEX-E-2.2.5		MSSB-E-2A/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
29	**Level 2**	GEX-E-2.2.6		MSSB-E-2A/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
30	**Level 2**	GEX-E-2.2.7		TBA	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
31	**Level 2**	GEX-E-2.2.8		MSSB-E-2B/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
32	**Level 2**	GEX-E-2.2.9		MSSB-E-2B/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
33	**Level 2**	GEX-E-2.2.10		MSSB-E-2B/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
34		**Relief Air Fans**																					
35	**Level 3**	RAF-E-3-1.2		MSSB-E-4A/FE	Off	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
36	**Level 3**	MFSD-E-4.12	RAF-E-3-1.2		Closed	Open	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
37	**Level 3**	MFD-E-3.24	RAF-E-3-1.3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
38	**Level 3**	RAF-E-3-1.3		MSSB-E-4A/FE	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
39	**Level 3**	MFSD-E-4.1	RAF-E-3-1.3		Open	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
40	**Level 3**	MFSD-E-4.2	RAF-E-3-1.3		Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
41	**Level 3**	RAF-E-3-1.6		MSSB-E-4A/FE	Off	Off	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
42	**Level 3**	MFSD-E-4.5	RAF-E-3-1.6		Closed	Closed	Open	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
43	**Level 4**	MFD-E-3.31	RAF-E-3-1.7		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
44		**VAVs**																					
45	**Level 1**	VAV-E.3.1.8.1	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
46	**Level 1**	VAV-E.3.1.8.2	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
47	**Level 1**	VAV-E.3.1.8.3	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
48	**Level 1**	VAV-E.3.1.8.4	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
49	**Level 1**	VAV-E.3.1.8.5	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
50	**Level 1**	VAV-E.3.1.8.6	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
51	**Level 1**	VAV-E.3.1.8.7	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
52	**Level 1**	VAV-E.3.1.8.8	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
53	**BLD F Level 1**	VAV-E.3.1.8.9	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
54	**BLD F Level 1**	VAV-E.3.1.8.10	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
55	**Level 1**	VAV-E.3.1.8.11	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
56	**Level 1**	VAV-E.3.1.8.12	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
57	**Level 1**	VAV-E.3.1.8.13	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
58	**Level 1**	VAV-E.3.1.8.14	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal

Building E Level 1 - Fire Matrix

Line	Device Location	Device	Associated Plant	MSSB	Level 1															Bld F Level 1 Zone 3	All Zones Level 0	All Zones Level 2	Level 3 Zone 1
								Theatres															
					Zone 8	Zone 9	Zone 10	10.1	10.2	10.3	10.4	10.5	10.6	10.7	Zone 11	Zone 12	Zone 13	Zone 14	Lift Core				
59	BLD F Level 1	VAV-E.3.1.8.15	AHU-E-3-1.8	MSSB-E-1A/NE	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
60		Fan Coil Units																					
61	Level 1	FCU-E-1-1.1	Comms Room	MSSB-E-0A/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
62		Exhaust Fans																					
63	Level 1	GEX-E-1-1.1	FCU-E-1-1.1	MSSB-E-0A/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
64	Level 1	GEX-E-1-1.2	FCU-E-1-1.1	MSSB-E-0A/E	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
65		Fire Dampers																					
66	Level 1	MFD-E.0.01	AHU-E-3-1.2 Zone 1		Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
67	Level 1	MFD-E.0.02	AHU-E-3-1.2 Zone 2		Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
68	Level 1	MFD-E.0.03	AHU-E-3-1.2 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
69	Level 1	MFD-E.0.04	AHU-E-3-1.9/10 RA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
70	Level 1	MFD-E.0.05	AHU-E-3-1.10 SA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
71	Level 1	MFD-E.0.06	AHU-E-3-1.9 SA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
72	Level 1	MFD-E.0.07	AHU-E-3-1.7 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
73	Level 1	MFD-E.0.08	AHU-E-3-1.7 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
74	Level 1	MFD-E.0.09	AHU-E-3-1.7 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
75	Level 1	MFD-E.0.10	AHU-E-3-1.7 Zone 4		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
76	Level 1	MFD-E.0.11	AHU-E-3-1.3 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
77	Level 1	MFD-E.0.12	AHU-E-3-1.3 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
78	Level 1	MFD-E.0.13	AHU-E-3-1.3 RA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
79	Level 1	MFD-E.0.14	AHU-E-3-1.3 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
80	Level 1	MFD-E.0.15	AHU-E-3-1.4 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
81	Level 1	MFD-E.0.16	AHU-E-3-1.4 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
82	Level 1	MFD-E.0.17	AHU-E-3-1.4 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
83	Level 1	MFD-E.0.18	AHU-E-3-1.4 RA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
84	Level 1	MFD-E.0.19	AHU-E-3-1.6 Zone 4		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
85	Level 1	MFD-E.0.20	AHU-E-3-1.6 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
86	Level 1	MFD-E.0.21	AHU-E-3-1.6 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
87	Level 1	MFD-E.0.22	AHU-E-3-1.6 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
88	Level 1	MFD-E.0.23	AHU-E-3-1.5 RA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
89	Level 1	MFD-E.0.24	HEX-4-4.1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
90	Level 1	MFD-E.0.25	AHU-E-3-1.5 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
91	Level 1	MFD-E.0.26	AHU-E-3-1.5 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
92	Level 1	MFD-E.0.27	AHU-E-3-1.1 RA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
93	Level 1	MFD-E.0.28	AHU-E-3-1.1 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
94	Level 1	MFD-E.0.29	AHU-E-3-1.1 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
95	Level 1	MFD-E.0.30	AHU-E-3-1.1 Zone 2		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
96	Level 1	MFD-E.0.31	AHU-E-3-1.1 RA		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
97	Level 1	MFD-E.0.32	AHU-E-3-1.5 Zone 1		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
98	Level 1	MFD-E.0.33	AHU-E-3-1.5 Zone 2		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
99	Level 1	MFD-E.0.34	HEX-4-4.1		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
100	Level 1	MFD-E.0.35	AHU-E-3-1.5 RA		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
101	Level 1	MFD-E.0.36	AHU-E-3-1.5 Zone 2		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
102	Level 1	MFD-E.0.37	HEX-4-4.1		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
103	Level 1	MFD-E.0.38	AHU-E-3-1.5 RA		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
104	Level 1	MFD-E.0.39	HEX-4-4.1		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
105	Level 1	MFD-E.0.40	AHU-E-3-1.1 RA		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
106	Level 1	MFD-E.0.41	AHU-E-3-1.1 Zone 2		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
107	Level 1	MFD-E.0.42	AHU-E-3-1.1 Zone 1		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
108	Level 1	MFD-E.0.43	HEX-4-4.1		Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
109	Level 1	MFD-E.0.44	AHU-E-3-1.3 Zone 1		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
110	Level 1	MFD-E.0.45	AHU-E-3-1.3 Zone 3		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
111	Level 1	MFD-E.0.46	AHU-E-3-1.3 RA		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
112	Level 1	MFD-E.0.47	AHU-E-3-1.3 Zone 2		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
113	Level 1	MFD-E.0.48	GEX-3-1.1		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open
114	Level 1	MFD-E.0.49	GEX-3-1.2		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open
115	Level 1	MFD-E.0.50	GEX-3-1.3		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open
116	Level 1	MFD-E.0.51	AHU-E-2-1.8 Zone 2		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open
117	Level 1	MFD-E.0.52	AHU-E-3-1.3 Zone 3		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
118	Level 1	MFD-E.0.53	AHU-E-3-1.3 Zone 1		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
119	Level 1	MFD-E.0.54	AHU-E-3-1.3 Zone 2		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
120	Level 1	MFD-E.0.55	AHU-E-3-1.3 RA		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open

Building E Level 1 - Fire Matrix

Line	Device Location	Device	Associated Plant	MSSB	Level 1															Bld F Level 1	All Zones	All Zones	Level 3
								Theatres															
					Zone 8	Zone 9	Zone 10	10.1	10.2	10.3	10.4	10.5	10.6	10.7	Zone 11	Zone 12	Zone 13	Zone 14	Lift Core	Zone 3	Level 0	Level 2	Zone 1
121	Level 1	MFD-E.0.56	AHU-E-3-1.4 Zone 3		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
122	Level 1	MFD-E.0.57	AHU-E-3-1.4 Zone 2		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
123	Level 1	MFD-E.0.58	AHU-E-3-1.4 Zone 1		Open	Closed	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
124	Level 1	MFD-E.0.59	Lift Shaft		Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open
125	Level 1	MFD-E.0.60	AHU-E-3-1.8		Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
126	Level 1	MFD-E.0.61	AHU-E-3-1.8		Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed
127	Level 1	MFD-E.0.62	AHU-E-3-1.8		Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open	Open	Open
128	Level 1	MFD-E.0.63	AHU-E-3-1.8		Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open	Open	Open	Open
129	Level 1	MFD-E.0.64	AHU-E-3-1.8		Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed	Closed	Open	Open	Open	Open	Open	Open
130	BLD F Level 1	MFD-F-1.19			Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Closed	Open	Open	Open
131		Smoke Dampers																					
132	Level 1	MSD-E.0.01			Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
133	Level 1	MSD-E.0.02	AHU-E-3-1.2 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
134	Level 1	MSD-E.0.03	AHU-E-3-1.2 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
135	Level 1	MSD-E.0.04	AHU-E-3-1.2 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
136	Level 1	MSD-E.0.05	HEX-4-4.1		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
137	Level 1	MSD-E.0.06	AHU-E-3-1.6 Zone 1		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
138	Level 1	MSD-E.0.07	AHU-E-3-1.6 Zone 2		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
139	Level 1	MSD-E.0.08	AHU-E-3-1.6 Zone 3		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
140	Level 1	MSD-E.0.09	AHU-E-3-1.6 Zone 4		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
141	Level 1	MSD-E.0.10	AHU-E-3-1.4 RA		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
142	Level 1	MSD-E.0.11	AHU-E-3-1.4 RA		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
143	Level 1	MSD-E.0.12	AHU-E-3-1.6 Zone 4		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
144	Level 1	MSD-E.0.13	AHU-E-3-1.6 Zone 3		Open	Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
145	Level 1	MSD-E.0.14	HEX-4-4.1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
146	Level 1	MSD-E.0.15	AHU-E-3-1.3 Zone 3		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
147	Level 1	MSD-E.0.16	AHU-E-3-1.3 Zone 1		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
148	Level 1	MSD-E.0.17	AHU-E-3-1.3 Zone 2		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
149	Level 1	MSD-E.0.18	AHU-E-3-1.3RA		Open	Closed	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open

AHU	Air Handling Unit
FCU	Fan Coil Unit
FD	Fire Damper
GEX	General Exhaust Fan
MFD	Motorised Fire Damper
MSD	Motorised Smoke damper
SEF	Smoke Exhasut Fan
SPF	Stair Pressurisation Fan
TEF	Toilet Exhasut Fan
VAV	Variable Air Volume Unit

Notes:

These devices are located in Building F. This Fire Matrix should be read in conjunction with the Fire Matrix for Building F.

Fan could be designated as supply air, not exhaust, to pressurise lift shaft

This device could not be located.

1. This matrix is based upon a smoke management methodology advised by Normal Disney and Young Pty Ltd.
2. Drawings provided by Siganto and Stacey used to develop this matrix.
3. Stair Pressurisation Fans to operate off AS1668.1 controls, with in-duct smoke probe to be non-latching type, with time delay
4. Outside Air Units to operate off AS1668.1 controls, with in-duct smoke probe to be non-latching type, with time delay
5. EWS operation is outlined in a separate document (NDY FIRE ALARMS) describing the time delays and cascading requirements. These are not actioned in this document.
6. Heat Exchange Units to operate off AS1668.1 controls, with in-duct smoke probe to be non-latching type, with time delay